Star-land

1—In Starland

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THE PLANET SATURN

IN STARLAND

by

FANNIE DICKERSON CHASE

"The heavens declare the glory of God; and the firmament showeth His handiwork."

—*Psalm 19:1.*

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FOREWORD

There are many books on astronomy, a large number of which have been prepared by the great astronomers of the day, for use as textbooks. Some, however, tell the story of the heavens in a fascinating way for the general reader; but all of them, without exception, give credence to unscriptural theories of creation. "In Starland" was written that our young people might have the story of the heavens purged from the erroneous ideas that pervade more pretentious books.

The author desires that the reader, while learning of the glories of the sky, may always be cognizant of the most important truth of all,—that the worlds came not by chance or evolution, but were framed by the word of God; that He spoke and they "stood fast."

The purpose of this volume is merely to outline to the reader the story of the heavens as revealed in the combined research work of the world's leading astronomers. Only in a general way, therefore, can the author give credit where credit is due.

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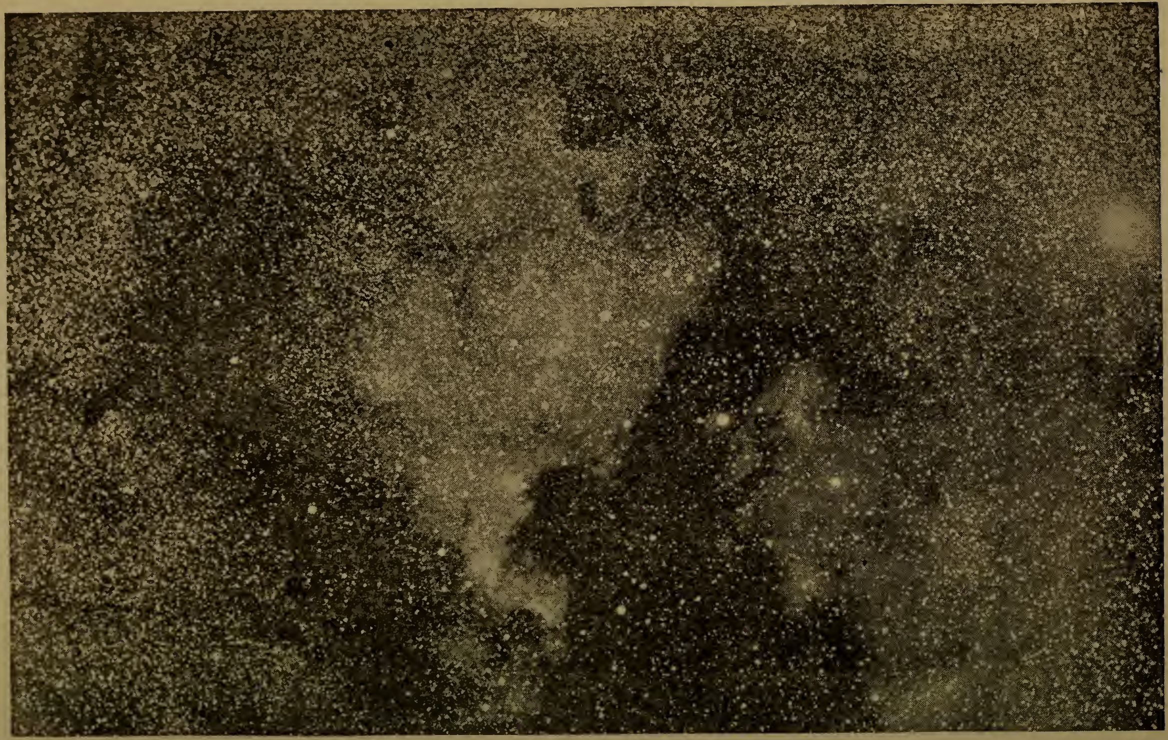


North American Nebula

I

THE UNIVERSE

"Lift up your eyes on high, and behold who hath created these things, that bringeth out their host by number: He calleth them all by names by the greatness of His might, for that He is strong in power; not one faileth." Isaiah 40: 26.

"A little cloud-ladder runs up to the blue.
Oh, would we could mount it, and take a peep through
To where stars and planets their lone vigil keep
Above us through sunshine as well as through sleep."

WE love the forget-me-nots of earth, and our pulse quickens at sight of their delicately tinted beauty. We press a cluster of them to our face with pleasure akin to that of friendship. So it is with the "forget-me-nots of the angels," the stars. Personal acquaintanceship with them — familiarity with their names, location, special charms, associates, times of rising and setting — gives us a friendly feeling toward them, so that we watch for their appearance with real interest. Such an acquaintanceship is not difficult to obtain, and requires little technical information. A nightly observation of the sky, under the direction of a guide, such as "In Starland" purposes to be, will richly reward the observer.

Ralph Waldo Emerson hinted at the too general lack of interest in the glories of the sky when he said, "If the stars should appear one night in a thousand years, how would men believe and adore and preserve for many generations the remembrance of the city of God which had been shown!" But because the Lord in His love grants us nightly this wonderful display, shall we neglect to show appreciation and interest? Shall we not the rather, in obedience to His invitation, eagerly lift our "eyes on high" in search of such matchless star jewels as Sirius, Arcturus, Spica, Capella, Vega, Altair, Antares, Regulus, Castor, Pollux, Betelgeuse, and Rigel, with many others; and also for the constellations they represent?

As we look up at the stars, we behold not separate and independent shining bodies, but members of starry families, or solar systems, of varying proportions. Most of these heavenly bodies that we see are supposed to be great central suns, around which, in immense concentric orbits, revolve worlds, each with its own moons, or satellites, sweeping around it, all bound together in one inseparable whole. At irregular intervals of time and space,

mysterious comets rush across the planetary orbits; and shooting stars and meteors dart hither and thither.

These myriads of systems, hung in space, are moving with inconceivable velocity, but in perfect order. That man might the better study and appreciate this immeasurable, ever-moving panorama, "his whole world turns him before it." He finds that "the sky is a vast immovable dial plate of that clock whose pendulum ticks ages instead of seconds, and whose time is eternity. The moon moves among the illuminated figures, traversing the dial quickly, like a second hand, once a month. The sun, like a minute hand, goes over the dial once a year. Various planets stand for hour hands, moving over the dial in various periods reaching up to one hundred and sixty-four years; while the earth, like a ship of exploration, sails the infinite azure, bearing observers to different points where they may investigate the infinite problems of this mighty machinery."

If there were no more to the handiwork of God than our own solar system, which preempts several octillion cubic miles of space, we could never fathom the wonders of His

power. But our system is only one of numberless systems, and one of the smallest. With our present telescopes, it is possible to photograph at least two hundred million stars, each perhaps representing one or more systems. The Lord Himself suggested the boundlessness of space, when He said, "If heaven above can be measured, . . . I will also cast off all the seed of Israel." But heaven cannot be measured.

Richter, in seeking to give an idea of the infinitude of the works of God, represents an angel as escorting a man through space to reveal to him the glory of the universe. He describes the imaginary flight thus: "So man and angel passed on, viewing the universe until the sun was out of sight—until our solar system appeared as a speck of light against the black empyrean, and there was only darkness. And they looked onward, and in the infinities of light before, a speck of light appeared, and suddenly they were in the midst of rushing worlds. But they passed beyond that system, and beyond system after system, and infinity after infinity, until the human heart sank and the man cried out, 'End is there none of the universe of God?'

The angel strengthened the man by words of counsel and courage, and they flew on again until worlds left behind them were out of sight, and specks of light in advance were transformed, as they approached them, into rushing systems; they moved over architraves of eternities, over pillars of immensities, over architecture of galaxies unspeakable in dimensions and duration, and the human heart sank again and called out, 'End is there none of the universe of God?' And all the stars echoed the question with amazement, 'End is there none of the universe of God?' And this echo found no answer. They moved on again past immensities of immensities, and eternities of eternities, until in the dizziness of uncounted galaxies the human heart sank for the last time, and called out, 'End is there none of the universe of God?' And again all the stars repeated the question, and the angel answered: 'End there is none of the universe of God. Lo, also, there is no beginning.'"

While this is but an imaginary incident, there is no doubt that could a person actually wing his flight through the universe of God, he would experience much the same

sensation of awe and wonder as is here depicted. Even when we can do no more than stand with head uplifted to the starry dome above us, contemplating the glories of the sky, "our hearts burn within us;" and we bow in reverence before the Power that created all these things, and created them for man's pleasure and profit. Surely man dishonors his Creator by taking little interest in this celestial display of His handiwork. True friendship with the stars strengthens one's friendship with God, and adds to the pleasure of life. Walt Whitman, in the following stanza, suggests the method of obtaining real, soul-satisfying companionship from the stars:

> "When I heard the learned astronomer,
> When the proofs, the figures, were ranged in
> columns before me,
> When I was shown the charts and diagrams, to
> add, divide, and measure them,
> When I sitting heard the astronomer where he
> lectured with much applause in the lecture room,
> How soon unaccountable I became tired and sick,
> Till rising and gliding out I wandered off by myself,
> In the mystical moist night air, and from time to time,
> Looked up in perfect silence at the stars."

II

GROWTH OF ASTRONOMICAL KNOWLEDGE

"O Lord, how manifold are Thy works! in wisdom hast Thou made them all." Psalm 104: 24.

"The heavens declare the glory of God; and the firmament showeth His handiwork." Psalm 19: 1.

MAN'S greatest triumphs of discovery have been in the study of the heavens; yet he has learned but little more than the astronomical alphabet, all his knowledge of the starry spheres being comprehended in this one science, while his knowledge of things in our own planet comprises many separate sciences.

However, from another point of view, and by comparison with the astronomical knowledge of the ancients, the astronomers of today, with the magnificent facilities at their command, are able to penetrate far into the mysteries of the heavens.

The ancients, without facilities or with pathetically meager ones, are credited with surprisingly clever observations. The Chinese take great pride in their early astronomical work, having the oldest record of an

The Great Egyptian Pyramids Testify to Astronomical Knowledge on the Part of the Ancient Dwellers by the Nile.

observed conjunction of the moon and four planets. They also claim credit for the first record of a solar eclipse.

Two of their chief astronomers, Ho and Hsi, unfortunately were put to death by order of the government for failing to announce a solar eclipse that took place in their time. The seriousness of their offense lay in the fact that eclipses were regarded as evidence of the wrath of the gods, so the performance of religious ceremonies for the appeasing of this wrath was imperative.

The Chaldeans, who lived in and about Babylon, were among the earliest of observers. Our present system of star groups, or constellations, began to be formed in those early times. The Chaldean shepherds, watching their flocks "under a sky famed for its clearness and brilliancy," discerned certain well defined groups of stars. By allowing the imagination considerable freedom, they saw men, women, horses, fishes, bears, birds, and other forms portrayed in these groups. Later, the Greeks gave names to such, and wove about them fantastic stories, which have been retained to the present time. Orion, for example, is represented under the figure

of a hunter assaulting Taurus, the bull. He has a sword in his belt, a club in one hand, and the skin of a lion over the other arm.

The great Egyptian pyramids, set square with the points of the compass, with their

ORION

TAURUS, THE BULL

openings facing the north and leading to passages parallel with the meridian, silently testify to astronomical knowledge on the part of the ancient dwellers by the Nile. With them, the heavenly bodies were objects of worship, and hence their risings and settings were systematically observed; but the Egyp-

tians contributed little to the progress of astronomy.

To the Greeks is given credit for the first genuine science of astronomy, though they borrowed the beginnings of their knowledge from the Babylonians and the Egyptians.

Thales, the chief of the "seven wise men" of Greece, lived more than six hundred years before Christ. Not only are we indebted to him for the part of geometry which treats of lines, and for the foundation of algebra, but he did much to awaken and keep alive an interest in astronomy. While he regarded the earth as a flat disk, he held that the moon shines by the reflected light of the sun. He determined the exact position of the sun in the heavens at the astronomical beginning of each of the four seasons, or in technical language, the time of the equinoxes and the solstices.

One of his most famous achievements was the prediction of the solar eclipse of 585 B. C., which terminated the war between the Medes and the Lydians. He also pointed out to navigators that as the Little Dipper

THE LITTLE DIPPER

was nearer the pole than the large, and the north star a part of it, it was a better guide for the mariner than the large one, which they were accustomed to use.

Pythagoras, a Greek philosopher, lived in the sixth century before Christ. He was partly contemporary with Thales. To him is accredited the honor of having raised mathematics to a science, even the name "mathematics" being ascribed to him. He it was who discovered that the square of the hypotenuse of a right-angled triangle equals the sum of the squares of the other two sides. He it was who discovered the numerical relations of the musical scale. But with all these achievements, he gave much attention to the study of astronomy. He founded a celebrated school at Crotona, in the southern part of Italy. Here he taught the rotation of the earth and that the planets were inhabited worlds. He was the first to conceive the earth to be a globe, self-supported in empty

THE LITTLE DOG

space ("And hangeth the earth upon nothing." Job 26:7), revolving with the other planets around a central body, not the sun, however. He retained, unfortunately, the idea of circular instead of elliptical orbits for the heavenly bodies. Had he been able to offer absolute proof for such of his theories as were really correct, astronomy would have been advanced many centuries. As it was, he was counted a dreamer; and in time, his best gifts to the science were forgotten.

Hipparchus, who lived in the second century before Christ, ascertained the length of the year within six minutes, and made the first star catalogue, locating definitely one thousand and eighty stars. The greatness of this achievement is manifest when we consider his lack of apparatus, and also reflect that this is about one fourth of all the stars that can be seen by the average person with the unaided eye. This work, including his division of the stars into six classes of brightness, or magnitudes, is pronounced by the "Encyclopædia Britannica" "one of the finest monuments on antique astronomy."

As an aid in astronomical calculations, he developed the science of trigonometry, not

completely, but in its beginnings. He also evolved an ingenious but cumbersome and erroneous system of "cycles and epicycles" in an effort to account for the motions of the planets and their satellites.

This theory made the heavenly bodies revolve in circles about the earth as the center. First came the moon, followed in order by Mercury, Venus, the sun, Mars, Jupiter, Saturn, each in its own orbit. Outside of all were the stars. While our earth is an important unit in the universe of God — at least, it seems so to us — yet it is by no means the center of the universe. Nothing but the moon revolves about it as a center.

In time, in the attempt to account for all the observed motions and deflections of the planets, the system suggested by Hipparchus grew more and more complicated, until at last a combination of several cycles and epicycles was necessary to make the planet Mars keep pace with the theory.

Strange as it may appear, this erroneous system was sufficiently ingenious to allow astronomers to predict the places of the planets so accurately that errors were not detected by the crude instruments then in use.

Hence its long life, satisfying the sages for more than a thousand years.

This system was based upon the idea that the earth was the center of the universe, and that the heavenly bodies revolved around it in circles at a uniform rate. While not one of these assumptions is true, this theory decided the future of Greek astronomy.

Ptolemy, who lived in the first half of the second century after Christ, espoused this theory of Hipparchus's, and expounded it in his famous "Almagest," which was used as a world textbook on astronomy for fourteen centuries. The system came to be known as the Ptolemaic theory. Ptolemy believed the earth to be spherical, but rejected its rotation.

During the early part of the sixteenth century, the astronomer Copernicus aroused the astronomical world from its complacent condition by reviving the theory of Pythagoras, which had been dead for a millennium. Copernicus saw "how beautifully simple is the idea of considering the sun the grand center about which the earth and other planets revolve. He noticed how constantly, when we are riding swiftly, we forget our own motion,

and think that the trees and the fences are gliding by us in the contrary direction. He applied this thought to the movements of the heavenly bodies, and maintained that, instead of all the starry host revolving about the earth once in twenty-four hours, the earth simply turns on its own axis, and this produces the apparent daily revolution of the sun and the stars; while the yearly motion of the earth about the sun, transferred in the same manner, would account for the solar movements."

Truth usually unfolds on the installment plan, one mind seemingly being unable to compass it all. So here, while Copernicus conceived many truths, he failed to grasp the correct idea regarding the paths, or orbits, of the planets. He saw that the idea of circular orbits would not explain all the observed phenomena, so he retained the system of "cycles and epicycles."

In six volumes, Copernicus set forth his theories of the solar system, these coming from the press as their author lay on his deathbed. Though the Roman Catholic Church carried this work on its prohibitory list from 1616 to 1757 A. D., as heretical and

unworthy of reading, Copernicus had herein laid the foundation of modern astronomy, upon which later astronomers have reared a substantial superstructure.

After Copernicus, Tycho Brahe, a Danish astronomer, who lived from 1546 to 1601 A. D., was the next to make a substantial gift to the science of astronomy. He was of noble birth, and was early adopted by a rich uncle, Jorgen Brahe, who sent him to Copenhagen to study philosophy and rhetoric. While there, he was impressed by the fact that a solar eclipse occurred at the exact time predicted. Thereafter astronomy seemed to him something divine. Procuring the works of Ptolemy and of other writers on the heavens, he became deeply interested in the science. But at this time, astronomy, then closely associated with astrology, was in general disrepute, because it stood so largely for conjectures and superstitions. Tycho's uncle, sharing the general feeling, forbade the youth's having anything to do with the study of the stars while at the Leipzig University, where he had been sent to perfect himself in law. But Tycho's interest in the planets and the stars was as great as his lack of interest

in law; so he managed secretly to prosecute his study of the heavens. After his uncle's death, which occurred within a few years, he was free to direct his time and studies more to his liking.

It may be of interest to note that Brahe took part in a duel, then considered an honorable way of settling disputes, and unfortunately lost his nose in the fray, thereafter wearing a substitute made of copper.

On returning to Denmark, he entered upon his life work. His reverence for God's handiwork was so great that he always clad himself in his velvet robes of state before entering his observatory, where he "watched the heavens with the intelligence of a philosopher and the splendor of a king," making astronomical observations that attracted much attention. He had the advantage of his predecessors in being a man of wealth, and a friend of the Danish king, who placed at his disposal large appropriations from the government. With these, he erected on the island of Hven a magnificent observatory, equipped with rare and costly instruments. For twenty years, he devoted himself assiduously to his observatory work.

Though this was before the day of the telescope, Brahe, with the aid of the apparatus at his command, was able "to place astronomy on an entirely new basis—that of exact observation." This was virtually the beginning of the science of astronomy. Hitherto, scientific men oscillated like the pendulum of a clock, from one astronomical theory to another, all of which contained some truth but more error. Brahe's legacy to the science of astronomy was a vast fund of astronomical data, the result of years of patient and zealous work.

Like many other men of high achievement, he became a victim of jealousy and injustice. His good friend King Frederick having died, the son who succeeded to the throne allowed himself to be influenced by jealous nobles, who brought charges against the astronomer. These led to the withdrawal of Tycho's pension and forbade his continuance of his astronomical observations. As this meant a virtual exile from the land of his birth, he removed to Bohemia, taking his observatory instruments with him. His adopted country honored him with an important position; but the hurt of the injustice he had suffered was

so deep that he early sickened and died. During his last illness, he was heard to say warmly, "O that I may be found not to have lived in vain!"

Tycho was not able to apply to the greatest advantage the valuable data he had secured; therefore he requested that his assistant, Johann Kepler, use his instruments and observational data, and if possible, from them establish a correct theory of the universe. Kepler took this mass of facts and figures, and developed from them laws that solved the question of the motions of the planets, and of their times of revolution. But jealousy on the part of Tycho's son-in-law robbed Kepler of the use of the astronomer's valuable instruments.

The story of Kepler's work is as fascinating as his work is important. Dr. J. D. Steele gives an especially interesting account of how Kepler developed his first great law:

"At that time, all believed the orbits of the heavenly bodies to be circular. They reasoned thus: The circle is perfect; it is the most beautiful figure in nature; it has neither beginning nor ending; therefore it is the only form worthy of God, and He must have used

it for the orbits of the worlds He has made. Imbued with this romantic view, Kepler began with a rigorous comparison of the places of the planet Mars as observed by Brahe, with the places as stated by the best tables that could be computed on the circular theory. For a time, they agreed; but in certain portions of the orbit, the observations of Brahe would not fit the computed place by eight minutes of a degree. Believing that so good an astronomer could not be mistaken as to the facts, Kepler exclaimed, 'Out of these eight minutes, we will construct a new theory that will explain the movements of all planets.'

"He resumed his work, and for eight years continued to imagine every conceivable hypothesis, and then patiently to test it—'hunt it down,' as he called it. Each in turn proved false, until nineteen had been tried. He then determined to abandon the circle and adopt another form. The ellipse suggested itself to his mind.

"With this figure, he constructed an orbit having the sun at the center, and again followed the planet Mars in its course. But very soon there was as great a discrepancy between

the observed and computed places as before. Undismayed by this failure, Kepler assumed another hypothesis, and determined to place the sun at one of the foci of the ellipse. Once more he 'hunted down' the theory. For a whole year, he traced the planet along the imaginary orbit, and it did not diverge. The truth was discovered at last, and Kepler in 1609 announced his first great law:

"'Planets revolve in ellipses, with the sun at one focus.'"

Kepler, in continuing to study the motion of the planets, found that a planet's speed in its path around the sun is constantly varying. Later he was able to deduce his second law:

"A line connecting the center of a planet with the center of the sun passes over equal areas in equal times."

The accompanying diagram readily interprets this law to the eye. Since the areas of the dark triangles are equal, and the planet passes over the varying bases of the triangles in the same time, it must travel much faster in passing from P_1 to P_2, the larger distance, than in passing from P_3 to P_4.

This able astronomer could not, however, tell what causes a planet continually to

change its speed in this way; but he accomplished much in determining that it does so, and that it moves according to definite law.

Kepler now set for himself another great task. He determined to discover whether there is any fixed relation between the times

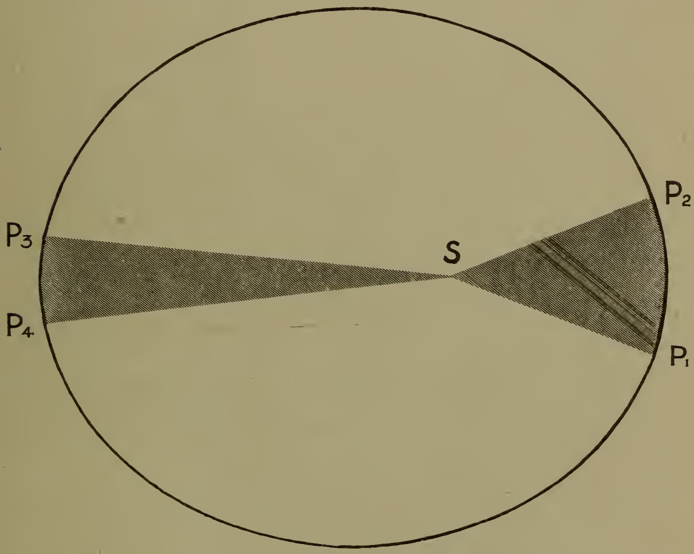


Diagram illustrating Kepler's first and second laws. The eccentricity of the earth's orbit is here greatly exaggerated, to show more clearly the varying speed of the planets in their elliptical journey around the sun.

S represents the center of the sun; P_1, P_2, P_3, and P_4 represent the center of a planet in four positions. A planet would travel from P_1 to P_2 in the same time that would be required for it to travel from P_3 to P_4. The area embraced by the lines P_1, P_2, S, is exactly the same as the area P_3, P_4, S.

required for planets to revolve about the sun and their distances from the sun. Again using the figures of Tycho Brahe, he began to compare them, arranging them in every conceivable relation. Finally, nine years after the discovery of his first law, he announced his third:

"The squares of the times of revolution of the planets about the sun are proportional to the cubes of their mean distances."

This means that to obtain the average distance of a planet from the sun, we should regard the earth's period of revolution as one year, and our distance from the sun as unity, then square the planet's time of revolution, and extract the cube root of the result, which gives us the planet's mean distance from the sun as compared with our own.

For example, Uranus, which is next beyond Saturn, makes a revolution in eighty-four years; the square of eighty-four is seven thousand and fifty-six; the cube root of which is nineteen and eighteen hundredths. The mean distance of Uranus from the sun is therefore nineteen and eighteen hundredths times our own mean distance, or nineteen and eighteen hundredths times ninety-three mil-

lion miles, or one billion, seven hundred and eighty-two million miles.

The discovery of these laws was a wonderful achievement; and when Kepler concluded his work, he exclaimed with rapture: "Nothing holds me. The die is cast. The book is written, to be read now or by posterity, I care not which. It may well wait a century for a reader, since God has waited six thousand years for an observer."

At this stage of the progress of astronomical science, a telescope was needed perhaps more than anything else; and Galileo, Italy's most famous philosopher and physicist, who lived from 1564 to 1642 A. D., provided the needed instrument—just a piece of lead pipe with a specially devised lens set at each end, but it was destined to accomplish marvels for the science of astronomy. When Kepler perceived the possibilities of the new instrument, he exclaimed: "O telescope, instrument of much knowledge, more precious than any scepter! Is not he who holds thee in his hand made king and lord of the works of God?"

Galileo himself had the good fortune, on January 7, 1610, to discover with his new instrument four of the moons of Jupiter; and

not until nearly three hundred years later, in 1892, was a fifth moon observed. Galileo made many other important discoveries with his telescope, though it magnified only thirty-three diameters, while the Mt. Wilson telescope is capable of magnifying ten thousand diameters.

Galileo was one of the world's most gifted men intellectually. His talents compassed a large range; for he could have brought fame to himself as musician, painter, orator, mathematician, inventor, physician, or philosopher. Fortunately, we think, his interest in astronomy and physics superseded other interests, and his name is inseparably connected with the development of these sciences. He early adopted the Copernican theory regarding the sun, instead of the earth, as the center of our solar system; but for a long time, from fear of ridicule, he was deterred from publicly expressing this belief. He also believed in the rotation of the earth, and was the first to describe the mountainous character of the moon's surface, and one of the first to suggest that the moon is a dark body shining by the reflected light of the sun. Hitherto, moonlight was generally regarded

as a kind of "phosphorescence" inherent in that body. Galileo was the first, too, to reveal the starry character of the Milky Way, and the librations of the moon. Many other discoveries might have been his, had he not been harassed, threatened, and finally imprisoned by the Catholic clergy of his time, who held that his ideas of the solar system and of the rotation of the earth were contrary to Scripture and hence heretical.

Even after Galileo's eyes, which had opened to the world such marvelous things, were forever closed in hopeless blindness, he continued his writing and study, making substantial gifts to science. It is interesting to note that the two great blind geniuses, Milton and Galileo, had the privilege of personal acquaintanceship after this tragic affliction came to the astronomer.

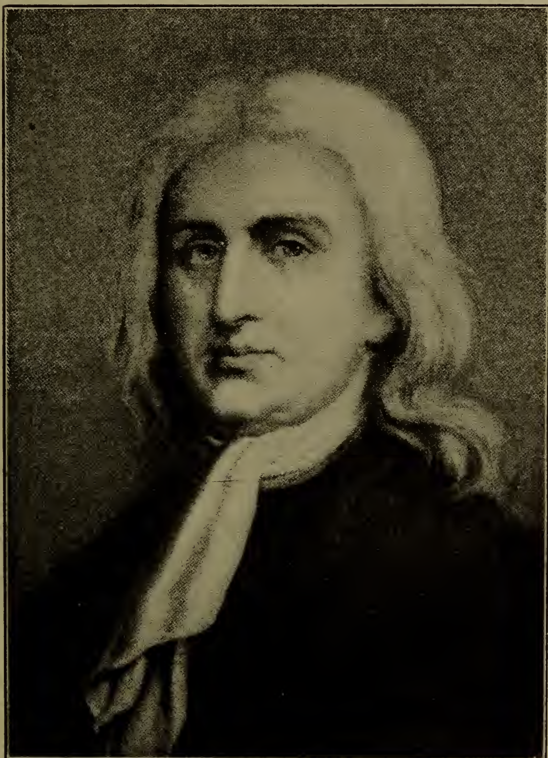
The year that Galileo died, Isaac Newton was born. He was destined to do for astronomy a work akin to that of Kepler. His philosophical mind demanded to know the why of things. When he saw an apple fall to the ground, he asked himself, Why did it fall to the ground? When he thought of the moon and the planets, he asked: Why do

they move in ellipses? What holds them in their course about the sun? When he thought of a planet's quickening its speed in portions of its orbit, he asked, What causes it to do this? Then again he asked, If one were up in space and should throw a stone, where would it go — in what direction and with what speed would it travel?

A question was to Isaac Newton a challenge to find the solution; so for sixteen long years, he toiled over interminable columns of figures, in an effort to find the answer to these questions. At last, he announced his first law of motion:

"Every body continues in a state of rest or of uniform motion in a straight line, unless compelled to change that state by an external force."

From this law, he knew that if a planet were put in motion, and no force acted upon it to change its course, it would move on forever in a straight line; but Kepler had shown that the planets move in ellipses. What was the force that caused the planets to move in ellipses, was the problem Newton next set about to solve. He studied the moon and other heavenly bodies to find what directed



Sir Isaac Newton

or regulated their motion. He finally reached the conclusion that the sun, by its attractive power, compelled the planets to revolve about him, "holding them with an irresistible power in their appointed paths." He found that the motions of the moon could be explained by assuming that the earth exerted an attractive force upon it, compelling it to circle around her. In time, he was able to announce the general law of gravitation: "Every particle of matter in the universe attracts every other particle of matter with a force directly proportional to its mass and inversely proportional to the square of the distance."

All bodies, then, according to Newton, are kept from flying away into space by the attraction of a greater body; and from falling into that body, by the speed with which they are revolving around it. Just so, when you whirl a ball tied to a string round your finger, the string keeps the ball from flying into space, and the rapid movement of the ball keeps it from falling toward your hand.

This law means that a body which has twice as much matter in it as another, will exert twice the attraction or pulling force of that other body, other things being equal; and also

that it will be pulled by a third body with twice the force of the other body, as it has twice as much matter to be pulled. Thus it is seen that gravity is proportional to the quantity of matter.

The second part of the law may be illustrated by the weight of an object on the earth and its weight when removed from the earth. If an aviator weighing two hundred pounds at the surface of the earth, four thousand miles from the center, could fly to twice that distance, or eight thousand miles from the center, he would weigh only one fourth as much, or fifty pounds. At sixteen thousand miles, he would weigh one sixteenth as much as he did at the surface, for he would be four times as far away. At the distance of the moon, two hundred and forty thousand miles, he would weigh one thirty-six hundredth of two hundred pounds, or one eighteenth of a pound, so far as the earth is concerned.

The time required for gravity to act between two bodies, however distant, is thought to be infinitesimal, or altogether negligible. At least, we are told that the speed of light is so incomprehensibly great that all other

velocities, when compared with it, seem as rest; so the quickness with which gravity acts when compared with the velocity of light makes light appear to be motionless.

The world's appreciation of Newton's great achievement is naively expressed by Pope:

> "Nature and nature's law lay hid in night:
> God said, Let Newton be! and all was light."

While Sir Isaac Newton gave to this power which holds the heavenly bodies in their paths the name of gravitation, yet he did not really know what gravitation is. Professor Charles Young, of Princeton, in speaking of gravitation, said: "It is inscrutable. If I were to say what I really believe, it would be that the motion of the spheres of the material universe stand in some such relation to Him in whom all things exist, the ever-present and omnipotent God, as the motions of my body do to my will. I do not know how and never expect to know."

> "In Him all things consist;
> Are held together by His power:
> The weight of worlds; a wealth of mist;
> The petals of a flower."

While scientists may not understand the nature of the mysterious force that holds

every sun and world in its appointed path, all must acknowledge that there is a very precise, definite, and intelligent adjustment between the amount of matter in a given body and its position and motions in the universe.

If the sun weighed more or less than it does, the attraction upon the earth would be increased or lessened in proportion to the sun's change in weight, and the entire balance of the solar system would be affected accordingly. Therefore it is not unwise nor unscientific to believe that the nice adjustment which characterizes the entire heavens is due to the fact that the Creator of all things "hath measured the waters in the hollow of His hand, and meted out heaven with the span, and comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in a balance." Isaiah 40:12. Surely "by Him all things consist," or hold together!

III

CIRCLES AND MEASUREMENTS OF THE CELESTIAL SPHERE

"He . . . sitteth upon the circle of the earth." Isaiah 40: 22.

BEFORE attempting an intelligent acquaintance with the heavens, it is desirable to understand certain astronomical terms and systems of measurements. This is not a difficult task if one insists on the imagination's acting its part acceptably.

Think first of the great blue dome of the heavens, the sky, as part of a great hollow sphere with the observer at the center, and all the stars and planets attached to its inner surface. This imaginary sphere is called the celestial sphere. The stars are at very unequal distances from us; but they all appear projected upon the inner surface of this great sphere. No observer can see more than one half of this sphere at a time; and if we imagine a plane cutting through the center and dividing the sphere in halves, the circle made by the cutting plane is the astronomical horizon. The actual or visible horizon is more or less irregular, and is the plane that

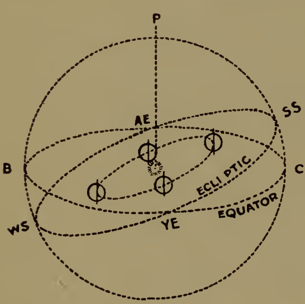
touches the surface of the earth where the observer stands, and extends out to the celestial sphere, separating the visible portion of the celestial sphere from the invisible. The point directly over the observer's head is the zenith, and the point directly below him is the nadir. The line connecting these passes through the center of the earth.

Think of the earth as within the celestial sphere, the centers of the two spheres coinciding, and the poles of the celestial sphere being the point in the heavens opposite the poles of the earth; then the celestial equator is the intersection of the plane of the equator of the earth (extended out on all sides) with the celestial sphere.

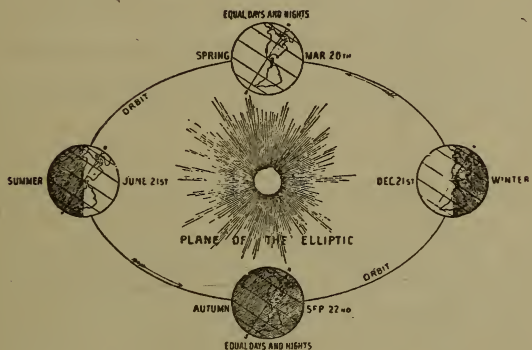
As the earth revolves in its orbit, a person on the earth looking out at the celestial sphere, which is at an infinite distance from him, will see the sun at a point on this sphere opposite to his own position. Day after day, as the earth moves on in its orbit around the sun, this orb will appear at a different place in the celestial sphere, finally seeming to have made a circuit of the heavens. The sun, therefore, because of the revolution of the earth about it, seems to traverse the same

path that the earth would, to an observer on the sun. This apparent path of the sun in the heavens is the ecliptic, and is found by extending the plane of the earth's orbit out to meet the celestial sphere.

If the earth revolved with its axis perpendicular to the plane of its orbit, and its center in that plane, the celestial equator, which is the plane of the earth's equator extended, would coincide with the ecliptic. But since the axis of the earth is inclined twenty-three and a half degrees to the plane of its orbit, the equator of the earth is lifted up from the plane twenty-three and one half degrees; so the two great celestial circles intersect at this angle, one half of the equator being above the ecliptic, and one half below. If you will secure two barrel hoops and place them so that they intersect at an angle of twenty-three and one half degrees, they will represent the two great celestial circles, and perhaps make clearer what follows.



As the sun moves along in the ecliptic, evidently it must cross the intersecting points, which are called the equinoctial points, or equinoxes. The points of the ecliptic most distant from the equinoctial points are the solstices, or solstitial points. The solstices are ninety degrees from the equinoxes.



The term "equinox" is taken from two words, one meaning equal and the other night. When the sun is at either of the equinoxes, the whole world has equal days and nights. The word "solstice" is taken from two words that mean sun and standing still, since, when the sun is at the solstices, or the tropics of Cancer and Capricorn, it seems to stand still for a brief time before starting on the return trip to the equator. At this time, the days

and the nights are most unequal at all places, except those on the equator.

The celestial equator is taken as the basis of the chief system of circles for locating heavenly bodies. It is a great circle, because the imaginary cutting plane that produces it passes through the center of the sphere. If the cutting plane passed outside the center, the result would be a small circle. The true or astronomical horizon is a great circle.

THE EQUINOCTIAL SYSTEM OF CIRCLES

Let the imagination again picture the earth inclined to its orbit twenty-three and one half degrees. Then extend the equator of the earth out to meet the celestial sphere. The great circle so formed is the celestial equator, the main circle of the equinoctial system. In imagination, place a yellow crayon on the north celestial pole, which is just above the north pole of the earth, and draw on the celestial sphere a line extending to the south pole, and on around to the north pole again. Draw a large number of these circles. These lines are the circumferences of the great circles of the celestial sphere, and are called

hour circles. Next measure off on one of these lines a degree, and draw on the celestial sphere a circle parallel to the celestial equator. One degree above this small circle, draw another parallel to the equator. Draw many of these. Divide the portion of the celestial sphere south of the equator into a large number of similar small circles. These are the *parallels of declination.* Now we have a system of circles by which any star may be located.

To locate a place on the earth, we must know how far it is north or south of the equator, and how far east or west it is from a certain meridian. That is, we must know both its latitude and its longitude. To locate a heavenly body, we must also know the relation of that body to two great celestial circles that are at right angles to each other, the celestial equator and an hour circle. The hour circle chosen for this work is the one passing through the first point of Aries, or the vernal equinox, one of the points where the ecliptic cuts the equator, the point through which the sun passes in the spring. This "hour circle is the Greenwich of the sky,"

and is of as much service to astronomers as the Greenwich meridian is to our geographers.

A star's distance in degrees north or south of the celestial equator, measured on the hour circle passing through the star, is its *declination,* which corresponds to latitude on the earth; and its distance measured eastward from the vernal equinox on the celestial equator is the star's right ascension, and corresponds to longitude on the earth. It may be expressed in degrees or in hours. Since the right ascension is measured eastward all around the circle, it may have any value from zero degrees to three hundred and sixty degrees. To locate the vernal equinox, draw a line from Polaris through the most western part of Cassiopeia to the celestial equator; the point of intersection gives the "first point of Aries," or the vernal equinox. A line drawn from Polaris through Delta, the star in the Large Dipper where the handle joins the bowl, and prolonged until it meets the equator, marks the autumnal equinox.

The equinoctial system of circles enables the astronomer to map the heavens as the geographer maps the earth. By consulting

these charts, one can find in what part of the sky to look for a given star.

THE ECLIPTIC SYSTEM

We have but one terrestrial system of circles for locating places; but for celestial purposes, astronomers use three systems. One, in which the ecliptic is used where the celestial equator was used in the previous system, has been passed down from the ancients. This system consists of the ecliptic, the great circles perpendicular to it, and the small circles parallel to it; and by this system, a star's latitude and longitude are given, its latitude being its distance north or south of the ecliptic, and its longitude being its distance from the vernal equinox measured eastward on the ecliptic. This system of measurements should not be confused with terrestrial latitude and longitude.

THE HORIZON SYSTEM

The third system is based upon the horizon, with the zenith and the nadir as the poles. The small circles parallel to the horizon are called parallels of altitude, or almucantars; while the great circles passing through the zenith and the nadir, and cutting

the horizon at right angles, are vertical circles. Distance above the horizon, measured on the vertical circle passing through a heavenly body, is its altitude; and its distance from the zenith is its zenith distance. The celestial meridian is the vertical circle passing through the north pole, and the prime vertical is the one at right angles to the celestial meridian, or the vertical circle passing through the east and west points. Azimuth is the distance on the horizon from the south point around toward the west, to its vertical circle. Some writers express it in the same way as the "bearing" in surveying, that is, so many degrees east or west of north and south, measured on the horizon.

The navigator is especially dependent upon the horizon system of circles. For example, on every clear day during a transatlantic journey, the captain may, by use of the sextant, ascertain when the sun crosses the meridian. This gives him the noon hour for the place where the vessel is when the observation is made. Then by noting the altitude of the sun — that is, its distance above the horizon when it is on the meridian — he can find from printed astronomical tables the terres-

trial latitude of the place where the sun was to have that exact altitude at noon on that particular day. If he wishes to determine the ship's longitude also, he may note the difference between the local time as he found it by the sun, and the time of the ship's chronometer, which is set to correct Greenwich time. If there is a difference of just three hours, he knows that he is forty-five degrees from Greenwich, because there is a difference in time of one hour for every fifteen degrees in longitude between two places. This is evident from the fact that the sun passes over the whole circle of the earth, or three hundred and sixty degrees, in twenty-four hours, so would require one hour to pass over fifteen degrees. If the local time is faster than the chronometer time, he knows he is in east longitude; and if it is slower, that he is in west longitude.

At night, the navigator looks to the stars for aid in directing his vessel. He can tell, from his astronomical tables, when certain stars should appear on the meridian of a given place whose latitude and longitude are known. He notes when they do appear on

the meridian where the vessel is, and thus he ascertains his location.

This chapter may seem bewilderingly technical; but interest in the rest of the book is not dependent upon a full appreciation of what is here given. Yet, if you later meet with terms not altogether clear, it may be that reference to this chapter will make them more lucid. If so, it will have been worth while.

IV

"THE DAY-STAR"

"In them hath He set a tabernacle for the sun." Psalm 19: 4.

THE sun, or day-star, is one of the myriads of stars in the celestial sphere. It is the center of our solar system, which is composed of the sun; the major planets,—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune; the minor planets, about one thousand of which have thus far been discovered; the satellites, or moons, of the major planets, twenty-six in number; meteors, shooting stars, a number of comets, and the zodiacal light. All the planets, with their satellites, sweep around the sun in obedience to its attractive power.

The sun is a little less than ninety-three million miles from us — a short distance astronomically, but not short from our viewpoint, for an aviator flying night and day at the rate of one hundred and fifty miles an hour would not reach the sun for seventy years. A clock would have to tick without interruption for nearly three years before it would have ticked off as many seconds as

there are miles between us and the sun. However, this distance of the sun from the earth is the "yardstick" used in measuring distances connected with our system.

THE SIZE OF THE SUN

The sun is the biggest thing in our system. It measures nearly nine hundred thousand miles from pole to pole, while our earth's polar diameter is less than eight thousand miles. To make a globe the size of the sun, one million three hundred thousand worlds the size of the earth would be required. If the world were to swell to the size of the sun, and men were to increase in the same proportion, a man would be six hundred and twenty-five feet tall, towering seventy feet above the Washington Monument.

If a grain of small-size shot one tenth of an inch across is taken to represent the earth, then nothing less than a football nearly a foot in diameter can be used for the sun. The weight of the sun, estimated at 2,000,000,000,000,000,000,000,000,000 tons, also gives a hint of its size.

"If we had a contract to build the sun," says one, "and could deliver the material in

lots the size of the earth, every hour, night and day, one hundred and fifty years would be required to complete the task."

The sun, on account of its great mass, will attract a body three hundred and thirty-two thousand times as strongly as will the earth. Therefore a body falling freely under the sun's influence will fall four hundred and forty-four feet a second, instead of sixteen feet, as is true of the earth. One who weighs one hundred and fifty pounds on the earth would weigh twenty-seven and six tenths times as much, or more than four thousand pounds, on the sun. A terrestrial athlete, therefore, would be seriously handicapped in executing a "high jump" on the sun.

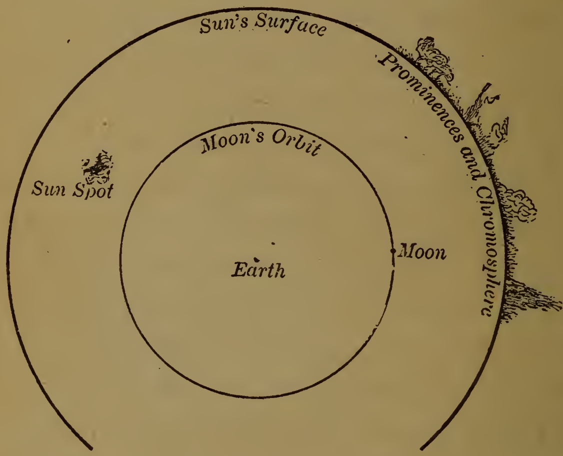
The sun's equatorial diameter, eight hundred and sixty-six thousand miles, is but the measure of the core of the sun. Outside of the part visible to the eye, there are gaseous envelopes that swell the size many thousands of miles.

STRUCTURE AND COMPOSITION OF THE SUN

The sun, so far as present astronomical knowledge extends, consists of a central mass, or nucleus. This is surrounded by a layer of luminous clouds, which is the part of the sun

visible to us day by day. It is called the photosphere, or light sphere, from *photos,* meaning light.

This luminous or light sphere is surrounded by a scarlet ocean of gas thousands of miles deep, an ocean much deeper than the Atlantic



is broad. This is the chromosphere, or color sphere, from *chroma,* the Greek for color. Under ordinary circumstances, the chromosphere is invisible, being "drowned in the light of the photosphere."

This great scarlet mass of turbulent flames was first seen during a total eclipse of the sun in 1605, when the red prominences of

THE SUN IN TOTAL ECLIPSE

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the chromosphere were observed jutting out far beyond the edge of the dark disk of the sun. For many years thereafter, the chromosphere was thought to be visible only at times of an eclipse; but thanks to the spectroscope, it may now be observed on any clear day. The average height of these chromospheric projections is found to be twenty-five thousand miles, though one measured three hundred and fifty thousand miles in height, and another four hundred and seventy-five thousand miles. These fiery fountains of gas attain a velocity of hundreds of miles a second, our "fiercest hurricanes being soothing zephyrs in comparison."

Outside of the chromosphere lies the corona, so called because "it crowns the king of day." It is an irregular pearly light of wonderful beauty, composed mainly of filaments and streams, which often radiate out from the sun more than a million miles. Its "pearly luster contrasts beautifully with the scarlet prominences, which stud it like rubies." Observers on Pikes Peak in 1878 are said to have seen streamers nine million miles long.

Though most beautiful and impressive, the corona is not substantial, being so thin, or

rare, that comets pass through it without suffering appreciable retardation of their movements. Astronomers therefore assert that it must be less dense than the best vacuums physicists can produce. Some think it is auroral in character.

By means of the spectroscope, astronomers have been able to determine the composition of the sun, having found more than forty of the well-known elements in it. Among these are aluminum, cadmium, calcium, carbon, chromium, cobalt, copper, hydrogen, iron, magnesium, manganese, nickel, silicon, silver, sodium, and zinc.

LIGHT AND HEAT OF THE SUN

The light of the sun is very real and important. A comprehensive idea of its brilliancy cannot be given by comparing it with artificial lights. The brightest electric arc light, when placed between the eye and the sun, will seem black by comparison. The light of five thousand five hundred and sixty-three wax candles held one foot from the eye will give a light comparable to the brilliance of the sun. Think of a bright full-moon night. Now place six hundred thousand such

moons in the sky, and you have the light of a June day. It is estimated that the light of seven hundred million stars as bright as Sirius, our very brightest star, would be required to equal the light of the sun; or the light of two hundred billion stars like the North Star. We must remember, too, that since the sun diffuses its radiance on all sides equally, we get a very small proportion of its light, not more than one two-billionth part of what it sends out into space.

The heat of the sun in midsummer, at our great distance from this fiery orb, is almost unbearable in certain latitudes; but if we were to come as near to it as the moon is to us, we would hardly have time to feel uncomfortable, for our old earth and all things upon it would be vaporized in less time than would be required to tell of the catastrophe. As in the case of the light of the sun, we receive only one two-billionth part of its heat; yet our annual ration would be sufficient to melt a layer of ice covering the entire earth to the depth of one hundred and twenty-four feet. It has "been calculated that if the sun were expending money instead of energy, at the rate of ninety billion dollars a year, the

earth's portion would be only forty-five dollars."

If the heat of the sun were produced by the burning of coal, it is estimated that a layer sixteen feet thick, extending over its whole surface, would be required to produce the heat given off in a single hour. Sir John Herschel estimated that if a solid cylinder of ice forty-five miles in diameter and two hundred thousand miles long were plunged into the sun, it would be melted in a second of time. Professor Young claimed that if the sun were frozen over completely to a depth of fifty feet, the heat emitted would melt the shell in one minute; and that if a bridge could be formed from the sun to the earth by a column of ice two and a fourth miles square and ninety-three million miles long, and if in some way the heat of the sun could be concentrated upon it, it would melt in a second of time, and be vaporized in seven more seconds. We are told that all known substances melt and vaporize under the focus of a powerful burning lens; yet this heat is not nearly so intense as that at the surface of the sun itself. In terms of thermometer readings, the sun's temperature is twelve thousand de-

grees Fahrenheit; while one of the highest terrestrial readings is that of the electric arc, which shows a temperature of six thousand degrees.

Though the heat of our sun is incomprehensible, it is altogether inconsiderable when compared with the heat of the central body of some of the other solar systems. Take for example Arcturus, the giant sun of the constellation Boötes. Mr. Garrett P. Serviss bids us "imagine the earth and other planets constituting our solar system removed to Arcturus and set revolving round it in orbits of the same forms and sizes of those in which they circle about the sun. Poor Mercury, for that little planet it would indeed be a jump from the frying pan into the fire; because as it rushed to perihelion, the point of its orbit nearest the sun, Mercury would plunge more than two million five hundred thousand miles beneath the surface of the giant star. Venus and Earth would melt like snowflakes at the mouth of the furnace. Even far-away Neptune would swelter in torrid heat."

How this great heat is maintained is a puzzling question to those set to solve the

problems of the skies. The generally accepted though unproved view is that the sun is shrinking slowly but continuously, and that the friction thus produced provides the necessary heat. If this be true, human reasoning might indicate that the sun would burn out after a few million years, and the earth be left to wander on in darkness; but no one who understands that the Creator of the universe maintains as well as creates, will have any undue concern over the future of the sun or the world. "God's in His heaven: all's right with the world!"

THE SUN SPOTS

The immense dark spots so often seen on the sun were long supposed to be deep temporary holes caused by violent electrical storms in the photosphere; but now the opinion exists that they are "due to ascending currents, material flowing outward from the sun's interior becoming cooler at the higher level, and therefore appearing dark against the brighter photosphere," they being "something like waterspouts at sea, the penumbra of the spot corresponding to the spreading top, and the darker umbra, to the stem." A cross section of these solar water-

spout formations would measure hundreds of miles, instead of a few feet, as is the case with our waterspouts.

SUN SPOTS

Their instability is noted in the fact that they sometimes increase or decrease in size while being observed; or they break up into two or more spots, or vanish altogether. On an average, they last two or three months, though they often remain but a week or a few days or hours. The longest record made by a sun spot was eighteen months. There may be hundreds of these at one time, and again none may be visible for weeks at a time. Some years, they are more numerous than in other years, reaching the maximum in number about every eleven years. At such periods, great magnetic disturbances occur on the earth. Auroral displays are most frequent and prominent at such times; so it is conceded by astronomers that there is a connection between the sun spots and our magnetic storms and northern lights, which are electrical displays.

The spots vary from fifty thousand to one hundred and eighty thousand miles in diameter. The earth, if tossed into almost any one of them, would be lost to view as is a small bowlder in the crater of a volcano. Sometimes a score of worlds like our earth could be laid in line across one of these spots without completely hiding it.

The sun spots aid in determining the time of rotation of the sun on its axis, which has been ascertained to be twenty-five and a fourth days. We are indebted to Galileo and his telescope for their discovery.

WHAT THE SUN DOES

The sun is the timekeeper for our solar system, ruling not only the day and the night, but also the year and the seasons. It "says to the earth wrapped in the mantle of winter, 'Bloom again;' and the snows melt, the ice retires, vegetation breaks forth, birds sing, and spring is about us."

The light of the sun, after passing through space for ninety-three million miles, streams unhindered through the glass in our windows, warming and lighting our homes. Only about three fourths of the heat from white-hot platinum can pass through glass; and only about six per cent of the heat from copper at seven hundred and fifty-two degrees passes through glass, ninety-four per cent being absorbed by it. We know that very little of the obscure dark heat from our stoves and furnaces passes out through the glass of our windows. If it were transmitted through glass as readily as the sunlight is, we should

find the artificial heating of our homes an almost impossible task. Herein is revealed a glimpse of that omniscience, that all-wisdom, displayed in thousands of other ways in the creation and adaptation of the earth for man's home.

The sun also has a strange chemical power. "It kisses the cold earth, and it blushes with flowers and moistens the fruit and grain. We are feeble creatures, and the sun gives us force. By it the light winds move one eighth of a mile an hour, the storm fifty miles, and the hurricane one hundred. The force is as the square of the velocity. It is by means of the sun that the fisherman's white-sailed ships are blown safely home. So the sun carries off the miasma of the marsh, the pollution of the cities, and then sends the winds to wash and cleanse themselves in the sea-spray."

It "says to the sea, held in the grasp of gravitation, 'Rise from your bed! Let millions of tons of water fly on the wings of the viewless air, hundreds of miles to the distant mountains, and pour there those millions of tons that shall refresh a whole continent, and shall gather in rivers fitted to bear the commerce and the navies of nations.' Gravitation

says, 'I will hold every particle of this ocean as near the center of the earth as I can.' Sunshine speaks with its word of power, 'Up and away!' and in the wreathing mists of morning these myriads of tons rise in the air, fly away hundreds of miles, and supply all the Niagaras, Mississippis, and Amazons of the earth." From these comes the power that turns the machinery of all the Lowells and Manchesters of the world. Surely it is not in vain that we heed the admonition to put our trust in Him who "calleth for the waters of the sea, and poureth them out upon the face of the earth: the Lord is His name." Amos 5:8.

Our great beds of coal are but the condensed sunshine of the antediluvian world, the magnificent vegetation that flourished before the Flood, now supplying our furnaces, lighting our homes, and running our factories, trains, and boats. In view of all this service, we exclaim, Well is it that "in them hath He set a tabernacle for the sun"!

> "The night has a thousand eyes,
>   And the day but one;
> Yet the light of a whole world dies
>   With the setting sun."

V

THE WANDERERS

"The worlds were framed by the word of God." Hebrews 11: 3.

"He commanded, and they were created." Psalm 148: 5.

A CLOSE student of the heavens night after night, will observe that several bright starlike bodies move about among the groups of stars. These are the planets, or wandering worlds, the term "planet" being taken from the Greek word for wanderer. Planets are often called stars, morning and evening stars; but they are not stars in the true sense, for stars are suns, supposedly with worlds, or dark bodies, revolving around them. Planets shine by the reflected light of the star around which they revolve, while the stars shine by their own light. The planets of our system, when viewed through a telescope, have an appreciable breadth, or disk; while the fixed stars still appear as points of light, so great is their distance from the earth.

The major planets of our system are eight in number, and named in their order from the sun, are, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The

minor planets form a group having their orbits between those of Mars and Jupiter.

Mercury and Venus, being within the orbit of the earth, are called inferior planets; and the five having their orbits outside the earth's are known as the superior planets. If you will make a drawing representing our solar system, and observe where the sun would appear on the sky as you look at it from the earth in various positions, then locate the inferior planets in the same way, you will see that these planets, Mercury and Venus, always appear in about the same part of the sky as the sun, Mercury never being seen more than twenty-eight degrees from the sun, and Venus never more than forty-eight degrees. Therefore, if you desire to find these stars when they are evening stars, you will need to look for them not far from the setting sun.

From your drawing, you may also observe that an inferior planet, as it revolves about the sun, is twice in conjunction with the sun — that is, in line with the sun as seen from the earth. When it passes between the earth and the sun, it is in inferior conjunction,

and its unlighted side is toward us. It is in superior conjunction when the sun lies between it and the earth; and in this position, it is always invisible, for the sun hides it from us.

When either of the inferior planets comes in direct line between the earth and the sun, it appears as a dark spot upon the sun. This is called a transit. There can never be a transit of a superior planet, as the orbits of these lie outside the earth's orbit.

When an inferior planet is east of the sun, it sets later than the sun, and therefore is an evening star; when it is west of the sun, it rises before the sun, and hence is a morning star.

The planets all move in elliptical orbits, with the sun at one of the foci. They move fastest when nearest the sun, or at perihelion — *peri* meaning near, and *helion* sun; and slowest when at aphelion, or the point in the orbit farthest from the sun.

The planets all rotate upon their axes from west to east; and they all move in that same direction around the sun, which is opposite to the motion of the hands of a watch.

If you live in north temperate latitude, you need not look for the sun, the moon, or any of the planets to appear in the sky north of your zenith, or the point directly over your head. All these will appear between the zenith and the southern horizon, in a belt only sixteen degrees wide, called the zodiac.

"THE SPARKLING ONE"

Mercury was called "the sparkling one" by the ancient Greeks, because, not appearing so high in the heavens as the other planets, its light passes through a thicker and more hazy layer of the atmosphere, and hence shines with a less steady, or a twinkling, light. It is the smallest of the major planets, having a diameter of about three thousand miles, and a volume one thirtieth that of the earth. It is also the nearest planet to the sun, its average distance from that luminary being thirty-six million miles. Thus a given area upon Mercury receives about seven times the heat and light an equal area on the earth would receive.

Mercury whirls about the sun at the rate of thirty miles a second, its period of revo-

lution being only eighty-eight days, less than one fourth the time required by the earth to make its revolution. Its time of rotation seems to be the same as its time of revolution. If this is true, "it is a world with two faces: one bathed in everlasting day, blistering under a scorching sun; the other wrapped in eternal night, freezing under the bitter cold of empty space." These conditions might be ameliorated by the character of the planet's atmosphere.

The most interesting phenomenon connected with Mercury is its occasional transit over the disk of the sun. This occurs when it gets into direct line between the earth and the sun, or when the planet is at one of its nodes. The transits are observed only in the early part of May and November; but this does not mean that they occur every May and November, for there were only thirteen transits of Mercury during the nineteenth century. The next one is scheduled to occur in 1924.

Mercury is best seen as evening star in the years when it is farthest east of the sun in March or April. If you remember that it

can never be very far from the sun, you will know where to look for it.

"THE QUEEN OF BEAUTY"

So brilliant is Venus that she was called by the ancients, Phosphorus, Lucifer, and Hesperus. "The shepherd's star" is another appropriate name given to Venus. She is sometimes bright enough to cast a shadow, and is often clearly visible in full daylight. Once when Napoleon went to Luxemburg to be feted, he was surprised, on his arrival, to find the populace more interested in observing a celestial object than in him or his brilliant staff. Upon inquiry, he found that they were observing what in their superstition they regarded as his star, the star of the conqueror of Italy. When the emperor himself recognized that it was Venus shining brightly upon them at midday, he too was interested. In June of 1921, Venus attracted much attention because of its daylight brilliancy, as that year it reached its maximum brilliancy, which occurs only every eighth year.

The excessive brilliancy of Venus is thought to be due in part to the cloudy condition of her atmosphere, as our great snow-white

cumulus clouds show that such masses reflect light better than the general landscape.

Venus is not visible at all times of year; so if you are anxious to make the acquaintance of this goddess of beauty, you should ascertain from an almanac, or from some other source, when she is to be morning or evening star. Like Mercury, she keeps near the sun, though she ventures considerably farther away than does that planet. If you find that Venus is to be evening star at a certain time, look for her in the western sky soon after sunset. If you miss seeing her on the evening planned, you need not allow your morning rest to be broken in an effort to redeem your failure; for Venus cannot be morning and evening star at the same time.

During the month of October, 1921, Venus, Mars, Jupiter, and Saturn were all morning stars, and appeared in a place in the sky not larger than the belt of Orion. Venus, being the swiftest traveler, swept past all the others, making a triple conjunction, such as occurs only once in twenty years.

Venus is seven thousand six hundred miles in diameter, in size almost a twin to the earth. She travels in the least elliptical orbit of all

the planets, and her mean distance from the sun is sixty-seven million miles. She is sometimes only twenty-five million miles from the earth. Her period of revolution is two hundred and twenty-five days, and it is thought that she completes a rotation in the same time.

Since Venus is an inferior planet, she like Mercury sometimes passes directly between the earth and the sun. Her transits are not so frequent as those of Mercury. There have been only seven transits of Venus since that of 1518, a period of more than four hundred years. The last one occurred in 1882, and no other is due until the year 2004. Others are scheduled to occur in 2012, 2117, 2125, 2247, since they occur at intervals of 8; 105½; 8; 121½ years.

It is interesting to watch Venus, with other heavenly bodies, meet the predictions of astronomers. Surely the prophet Isaiah was right when he said, "Not one faileth." An astronomer announces "that on such a year, month, day, hour, and second, a celestial body will occupy a certain position in the heavens. At the time indicated, we point our telescope to the place, and, at the instant, true beyond the accuracy of any timepiece,

the orb sweeps into view! A prediction of the Nautical Almanac is received with as much confidence as if it were a fact contained in a book of history. 'On the trackless ocean, this book is the mariner's trusted friend and counselor; daily and nightly its revelations bring safety to ships in all parts of the world. It is something more than a mere book. It is an ever-present manifestation of the order and harmony of the universe.'"

Early astronomers learned that a transit of Venus could be used in determining the sun's distance from the earth; so when the transit of 1761 was about due, a French astronomer, Le Gentil, was sent out to the East Indies by the French Academy, to make observations. At this time, France was at war with England, so "the English prevented his making his first port. High winds afterward kept him out at sea till the transit was over. He then resolved to remain abroad until after the transit of 1769. Eight long years passed, and the morning of June 3, 1769, dawned bright and beautiful. With his instruments all in place, Le Gentil was counting the moments for the long-awaited transit to begin; when, suddenly, the sky

grew black with clouds, and a tropical storm, the first in days, swept by. Meantime Venus came and went, and the ill-fated Le Gentil had again lost the opportunity of years. Prostrated by his bitter disappointment, it was two weeks before he could hold his pen to write the story of his second failure."

Fortunately, some have been more successful than Le Gentil. Horrox, an amateur astronomer living near Liverpool, and his associate, William Crabtree, were the first persons to observe a transit of Venus, and the only ones to observe the one of 1639. From calculations, it was decided that a transit must occur on December 24, 1639. Horrox began his observations on that day at sunrise. But true to his regular custom, when the hour for church arrived, he left his instrument and went to church. However, almost immediately on his return, there was a rift in the clouds which rendered the sun distinctly visible, and he says, "as if divine Providence encouraged my aspirations; when — oh, most gratifying spectacle! the object of so many earnest wishes! — I perceived a new spot of perfectly round form

that had just entered upon the left limb of the sun."

With Galileo's telescope, Venus vindicated the Copernican theory; for the claim had been made that if, as this theory held, the sun was the center of our system, and the planets revolved around it, Mercury and Venus should show all the phases of the moon. The telescope revealed the phases. And it is a curious fact that when Venus appears the very brightest to us that she ever does, she is only at the crescent phase instead of full; but she is then twice as near to the earth as she is at some other times.

VI

THE PLANETARY HOME OF MAN

"Speak to the earth, and it shall teach thee." Job 12: 8.

THE earth, like Mercury and Venus, is one of the heavenly bodies, and appears to other worlds as a bright star in the sky. It is the third planet of our system in distance from the sun, being a little less than ninety-three million miles from that luminary. It is larger than either Mercury or Venus, its equatorial diameter being seven thousand nine hundred and twenty-five miles, which would make its circumference at the equator about twenty-five thousand miles, and its volume two hundred and sixty billion cubic miles. Its weight is given as six thousand quadrillion tons.

THE SHAPE OF THE EARTH

The spherical form of the earth is now accepted as fact, though men were slow in giving credence to the idea. Some held that it was an immense flat, circular plane, after the order of a pancake, with a river flowing around it. Others thought it to be rectangular in shape. Plato thought it a cube, and

other celebrities said it was egg-shaped. Long before the days of Columbus, there were some who pronounced the earth a sphere, Pythagoras having used a sphere in his schoolroom; but Columbus is credited with being the first to venture boldly out upon a great undertaking based solely upon the idea of a spherical or oval surface.

So conclusive and abundant are the proofs that the earth is a sphere, that we now wonder that men so long held to the flat-earth theory, or to other equally erroneous ideas. Some of the observations that have settled the controversy over the shape of the earth follow:

The appearance of vessels approaching the shore indicates that the surface of the earth is convex, like that of a sphere, for the tops of the masts are seen before the hull.

The earth has been circumnavigated, practically from north to south, as well as from east to west. Magellan's three-year voyage around the world swept away much doubt. If the earth were cylindrical, like a stovepipe, it could be circumnavigated; but the circumnavigations have been so varied as to prove it spherical.

The shadow of the earth on the moon during lunar eclipses is always such as only a sphere casts.

If you were at the equator, the North Star would lie on your horizon; but as you pass from the equator toward the north, your horizon dips below the North Star, or the star is raised above the horizon, by an amount equal to the latitude. If one is in latitude fifty degrees, the North Star is just fifty degrees above the horizon. Only on a curved surface could the altitude of the star change with the latitude.

If one should dig down into the earth fifty feet perpendicularly, or radially to the surface, then extend the excavation at right angles to the perpendicular depth, it would gradually grow shallower. To maintain a mean depth of fifty feet, the depth must occasionally be corrected by steps.

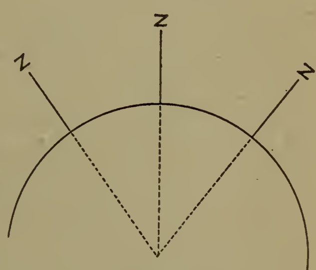
The fact that the middle one of three tall stakes set a long distance apart, and projecting equally above a body of still water, appears the tallest, proves the rotundity of the earth. To illustrate this point, set up on a book three small candles one inch apart, each projecting to an equal height above the sur-

face of the book. As you sight across them, they appear of equal length. Now if you take a football, and place the three candles on it in a line several inches apart, each projecting equally above the surface of the ball, and sight across them as before, the middle one will appear the tallest. This is because of the curvature of the ball. Years ago two men were discussing the shape of the earth, one asserting that it was flat, and the other, that it was round. Finally a large sum of money was wagered on the proposition. The one who won the bet, proved the curvature of the earth by setting up three stakes, a mile apart, in the Thames River. These projected equally above the water. Then to observers, the middle one appeared the tallest. The judges regarded this as sufficient proof of the curvature of the earth, to win the money.

In surveying, corrections or jogs are made at certain places in the north-and-south lines, on account of the curvature of the earth.

The fact that places have different zeniths and different noon hours is proof that the earth is a sphere. The zenith is the point in the sky directly overhead. If the earth were

a plane, the zeniths of two persons, or of a person at different points on the earth, would appear to be at a common point, as prolonged parallel lines appear to converge to the same point in the sky. Railway rails appear to meet at a distance of four miles. On a sphere,



the lines passing through the zeniths of different observers and the center of the earth would diverge rather than converge, so no two places would have the same zenith; and as this is the condition that exists, the conclusion is logical that the earth is a sphere. The same reasoning applies to the question of time.

The horizon of an observer at any point on the surface of the earth is always circular. This can be true only in case of a sphere.

While these facts prove the globular form of the earth, they do not prove it to be a perfect sphere. It has been found to be an oblate spheroid, that is, a sphere flattened at the poles and bulged at the equator, making the polar diameter less than the equatorial. There is a variation of nearly twenty-seven miles between these two diameters. Bodies weigh slightly less at the equator than elsewhere on the earth, and the weight increases as the body moves toward the pole, weighing most at the poles. A man weighing one hundred and ninety pounds at the equator would weigh one hundred and ninety-one pounds at the pole. This difference in weight is attributable to two causes. When a ball fastened to a string is whirled about the hand, it constantly tends to fly away from the center; the force producing this tendency is known as centrifugal force. The rotation of the earth causes a body to tend to fly away from its surface; and since the earth rotates fastest at the equator, the centrifugal force is the greatest there. Since this force acts in op-

position to gravity, the weight would be lessened — for the weight of a body is only the measure of the pull of gravity upon it.

The rotation of the earth does not account for all of the difference in weight between a body at the equator and at the pole. Assuming that the pole is just thirteen and five tenths miles, as it has been found to be, nearer the center of gravity, this would account for the increase of weight. As no other reason can be given for this increase of gravity manifested at the pole, it is logically attributed to the flattening of the earth at the poles. But the oblateness is actually demonstrated by the fact that the degrees of latitude grow larger toward the pole, showing that the curvature of the earth near the pole is part of a larger circle than that at the equator. The difference between a degree at the equator and one at the pole is over three thousand feet. On a perfect sphere, the degrees are equal.

While the surface of the earth-sphere seems very irregular to us, the distance between the highest mountain and the deepest part of the ocean bed being about twelve miles, yet on a globe fifteen feet in diameter, Mt. Everest

would be represented by a projection but one eighth of an inch high, and the greatest known ocean depth would be represented by a depression one seventh of an inch deep. On smaller globes, the irregularities become practically insignificant.

THE ATMOSPHERE

We live at the bottom of an atmospheric ocean that is as wonderful as the watery one that covers so large a part of the earth. The atmospheric ocean is conceded to be much deeper than the deepest place in the Pacific, its depth being variously estimated from fifty to five hundred miles. Clouds do not reach above ten or twelve miles.

The air is highly rarified above a height of six or eight miles, as aviators can testify, oxygen tanks being called into service long before a height of forty thousand and eight hundred feet is reached—the greatest distance that man has yet penetrated the atmospheric heights. As a rule, with each ascent of three and one half miles, the density of the air is halved; and for every ascent of three hundred feet, the temperature is lowered one degree.

This gaseous substance that completely envelops the earth is a marvelously inert but highly useful mixture of nitrogen, oxygen, argon, and carbon dioxide, with considerable water vapor. The first two gases form twenty-nine thirtieths of the whole atmosphere, argon and allied gases, with the carbon dioxide, forming the major part of the remaining thirtieth.

The total amount of carbon in the air is estimated to be sufficient to keep all our gardens and crops growing for twenty-two years, or a forest covering our whole globe for one third of that time.

Not until Galileo's time did scientific men admit that air exerted pressure, and therefore had weight. We are told that learned men discussed and experimented in an effort to ascertain whether air had weight, but always gave forth unblushingly a negative dictum. Yet the Scriptures had been saying, all through the centuries, that the Lord had given weight to the winds, or to the air. Finally one of Galileo's pupils solved the problem affirmatively by an interesting experiment. In the attempt to prove that the weight, or pressure, of the air made the water

rise in a water pump to a certain height, he took a glass tube four feet long, and, filling it with mercury, inverted the open end in a dish of mercury, whereupon the mercury fell a few inches, leaving a vacuum in the upper end of the tube, and a column of mercury thirty inches high in the tube. What made the mercury remain in the tube? Evidently it was the downward pressure of the air on the top of the mercury in the dish. Later experiments proved this to be true; for when the air was removed from the top of the mercury in the dish, the mercury would fall out of the tube, or when the air was removed from the tube and left upon the mercury in the dish, the air would push the mercury from the dish into the tube. Now Torricelli reasoned, If the pressure of the air will sustain a mercury column about thirty inches high, since water is only about one fourteenth as heavy as mercury, it should support a column of water thirty-two feet high, or fourteen times as high as the mercury column.

This being the height at which water is raised in an ordinary lift or suction pump, Torricelli boldly announced that the air has

weight, exerting at sea level a pressure of about fifteen pounds on every square inch of surface, or a ton to every square foot. The greater the height, the less the density. There are high plateaus where the pressure is hardly more than two thirds of what it is at sea level. The weight, or pressure, of the air forces the water of a well up into the pipe connected with the pump, after the air has been largely withdrawn from the inside of the pipe.

The air, through its weight and motion, is of inestimable service to man: it drives sailing vessels, windmills, and other machinery; makes possible various kinds of pneumatic service; supports the flight of birds; and scatters pollen grains and seeds. Through its composition, it maintains life by supplying oxygen and carbon dioxide to the plant world, and oxygen to the animal world. It supports combustion, through the union of its oxygen with the substance burned. It diffuses heat, cold, and moisture over the earth, through its circulatory currents. The climate of each planet is quite dependent upon the character of its atmosphere.

The atmosphere diffuses the light from the sun so that objects not in the direct rays are made visible. If it were not for this, the surface of the earth would be illuminated only where the direct rays fall. If it were not for the atmosphere, we should have a far less colorful world; for to it we owe the glory of sunrise and sunset. Halos and coronas, rings of light, sometimes beautifully colored, are frequently seen surrounding the sun and the moon. These are caused by the presence of minute particles of ice or water held in suspension in the atmosphere. We should also have an altogether silent or soundless world were it not for the air. How deeply we should appreciate this marvelous aërial provision for our comfort and pleasure, as well as for our very existence!

ROTATION OF THE EARTH

The earth rotates on its shorter axis from west to east, once in twenty-four hours, causing day and night, and the apparent rising and setting of the heavenly bodies. The earth, in its rotary motion, makes an accurate timekeeper; because the day is invariable, not a change of a thousandth of a second in a thousand years having been detected. How

significant in this connection is the question the Lord put to Job: "Hast thou commanded the morning since thy days; and caused the dayspring to know his place?" This work is not for man. Surely it is the Creator who, day after day, turns our great globe toward the sun "as clay to the seal."

Ptolemy and his successors rejected the theory of the rotation of the earth. Copernicus espoused the idea, but could produce no proof. His only argument was that there was more probability that the earth rotated than that all the heavenly bodies revolved around it. Even as late as the sixteenth century of the Christian era, the idea seemed sacrilegious to many; and Galileo, who believed in the rotation, was compelled by church authorities to recant or else suffer continued persecution. But the oft-told story is that he muttered to himself as he left the presence of his adversaries, "It moves just the same."

So it does; and the fact has been fully demonstrated, though no proof was given until 1851, when Foucault performed his celebrated pendulum experiment at the Pantheon in Paris. From the dome of the

Pantheon, he suspended an iron ball by a wire two hundred feet long, so that it could oscillate freely. The ball had a sharp style attached to it; and as it swung over a table strewn with sand, it left a mark in the sand. The fact that it never retraced its path, but always traced a new one a little to the right of the last mark, showed that the floor of the building was turning around under the pendulum, which phenomenon proved that the earth must be rotating from west to east.

An experiment that I have seen described, which you can perform in your own home, will prove to you that the earth moves, as conclusively as some of the expensive and complicated instruments in large laboratories: Nearly fill a large bowl a foot or more in diameter with water. Sprinkle the surface of the water with finely powdered resin, or some other powder that will not easily dissolve in water. Now sprinkle a straight line of coal dust about an inch wide upon the resin from the center to the circumference, continuing the line up over the edge of the bowl. After an interval of several hours, you will find that the black line on the surface of the water and that on the bowl do not

now coincide as they did when made. The only conclusion that can be drawn from this observation is that "the bowl has been carried round by the motion of the earth and twisted from its original position, but the water in the bowl, being free to turn, has not been moved so much. In other words, the earth swung through a considerable arc from west to east, and left the water almost stationary."

Another experiment gives equally conclusive proof of the rotation of the earth. Drop a ball from some high tower, as the Washington Monument, and note where it strikes the ground. You will find that it does not strike the ground at a point radially below the one from which it was dropped, but always at a point to the east of that. While it is falling, the earth, by its rotation, carries it eastward, making it fall to the east of a radial line drawn from the top of the tower.

Our trade and anti-trade winds, with the ocean currents, testify to the rotation of the earth; for they would have a north-and-south direction were it not that the rotation of the earth deflects them from this course. For example, take the trade winds. The air over the equator, becoming intensely heated, is

pushed up and out by incoming currents of heavier air from points north or south of the equator. These cold currents have the speed of rotation that the earth had at the point from which they started, which is slower than for the equator. As they move toward the equator, they are unable to keep up with the rapid eastward motion of the earth, and fall behind the meridian, or the north-and-south lines, making the northern wind seem to come from the northeast, and the southern one from the southeast.

The anti-trades are subject to the same influence; but as they start from the equatorial regions, where the velocity of rotation is greater than it is where the currents come down nearer the surface of the earth, they get ahead of the meridian, and so appear to come from the northwest and the southwest.

Were the atmosphere to fail to move with the earth as it turns over at its great speed, we should not prosecute our journey so peaceably as we now do, but should be caught in a fearful cataclysm, our severest tornadoes being small affairs in comparison.

Since at the equator the earth is approximately twenty-five thousand miles in cir-

cumference, a person at the equator is whirled through space by the rotation of the earth at the rate of a thousand miles an hour; but the circumference of the earth decreasing toward the pole, the speed of the earth at a point between the equator and the pole is less than at the equator. The speed at which New York City travels is about seven hundred and eighty miles an hour; and of a place at the mouth of the St. Lawrence, six hundred and eighty-two miles; while at the pole, the rate is zero. The apparent motion of the stars is affected accordingly.

The rotation of the earth permits an extended view of the heavenly bodies during an evening's observation, as there is an ever-moving panorama passing before one. The rotation also causes sun, moon, and stars to appear to rise in the east and to set in the west, since the earth is actually moving in the opposite direction. This seems an easy problem to us, but it was the stone of stumbling to astronomers until the time of Copernicus.

The sun rises in the exact east shortly after the middle of March; then the next day, it rises a little to the north of east; and a little farther to the north each succeeding day,

until on the last of June or thereabouts it rises twenty-three and a half degrees north of east. Then it begins to retrace its course, rising a little farther south each succeeding day, until in September it again rises in the exact east. After this, it rises a little farther south each succeeding day, until it reaches a point just twenty-three and a half degrees south of the east point, when it starts on its northward journey. The sun thus seems to travel back and forth within a space of forty-seven degrees, crossing the equator, or the east point, twice each year. This swinging or oscillatory motion is due to the sun's apparent motion in the ecliptic, which is inclined to the celestial equator at an angle of twenty-three and a half degrees.

The vernal equinox is the time the sun rises in the exact east point on its northward journey; the summer solstice is the time it reaches the point farthest north, or the Tropic of Cancer; and the time when it crosses the equator again after three months is the time of the autumnal equinox; then, as it passes on to the south, it reaches its most southern point, the Tropic of Capricorn, at the time of the winter solstice. The vernal equinox,

then, marks the beginning of spring, and the autumnal equinox the beginning of fall.

The problem of the inequality of our days and nights, so vexing to some, becomes perfectly clear when one challenges the imagination to picture clearly what takes place as the sun makes its daily journey across the sky. Think of the sun as being in the exact east point. As the earth rotates, the sun shines down perpendicularly over every part of the equator, leaving, as it were, a golden circle about the earth at the equator. Now think of the sun as rising ten degrees to the north of the equator. While it is in that position, the earth makes a rotation, which causes the sun to shine down perpendicularly over a circle ten degrees to the north of the equator, leaving a golden circle of light about the earth ten degrees north of the equator. Later the sun rises fifteen degrees to the north of the east point; and as the earth rotates, there is left a golden circle about the earth fifteen degrees north of the equator. Again it rises twenty-three and a half degrees to the north of east, the farthest northern point it ever reaches; so a golden line is traced on the earth that coincides with the

Tropic of Cancer. As it traverses the return southern journey, it will on successive days trace the same golden diurnal circles that it did when going north. As it reaches the east point again, it traces a line all about the earth at the equator. When it reaches its farthest southern point, it travels in the Tropic of Capricorn, twenty-three and a half degrees south of the equator. The sun therefore traverses as diurnal circles, the year around, the equator or the circles parallel to the equator.

Now, as the true horizon of any place on the equator passes through the center and poles of the celestial sphere, it will cut all diurnal circles in halves; so the sun would be above the horizon just as long as it would be below, and hence the days and the nights at points on the equator are always of the same length. By making a drawing to show how the horizon of any given place cuts the diurnal circles, one can tell the relation of the day and the night at any time of year.

If a person is in north latitude thirty-five degrees, his horizon will dip below the north pole just thirty-five degrees. It will therefore cut all diurnal circles, except one, un-

equally. The longer part of the circles north of the equator being above the horizon, the days will be longer than the nights, as is true from March to September, while the sun rises north of the equator. The part of the diurnal circles above the horizon while the sun is south of the east point, is smaller than the part below the horizon; hence the days are shorter than the nights from September to March.

When the sun rises at the precise east point, as it does in March and September, it traverses the celestial equator as a diurnal circle; hence all places on the earth have equal days and nights twice each year, for every horizon divides the equator into halves.

A person at the north pole would have the equator for a horizon. So in March, the sun would pass around the horizon, never setting; and all the time from March to June, it would be climbing a little higher up in the heavens, but would be traveling in diurnal circles parallel to the equator, yet never setting. By September, it would again be at the horizon line. Then it would pass below the horizon, not to be seen for six months. But this does not mean that there would be absolute darkness at the pole for six months.

The long twilight and the moon help to shorten the period of absolute night to about three weeks. Only a few degrees' removal from the pole is sufficient to cause the period of utter darkness to vanish entirely.

THE REVOLUTION OF THE EARTH

The earth completes a revolution about the sun in three hundred sixty-five and one fourth days. In that time, it travels nearly six hundred million miles; hence its average speed is more than eighteen miles a second, or a million and a half miles a day. Drop a ball from the height of four feet. In the time the ball takes to reach the floor, the earth will have given us all a free ride of more than nine miles.

The revolution of the earth brings a different set of stars into our view at different seasons; and the revolution, with the fact that the axis is inclined twenty-three and a half degrees, and that as the earth revolves, the pole always points to the same part of the heavens, produces our seasons.

TIME PROBLEMS

When the sun crosses the meridian of a place, it is noon at that place; and the time

that intervenes between two successive transits of the sun across the meridian constitutes a solar day. The time that elapses between successive transits of a star across the meridian is a sidereal day. The latter is the true day, registering the exact time of a rotation of the earth. It is 23 hours, 56 minutes, and 4.09 seconds long.

A solar day is twenty-four hours long. This comes from the fact that while the earth is making a rotation, it moves on in its orbit nearly a degree, and thus it has to continue to rotate a little farther before it meets the sun, which, because of the rotation of the earth, has apparently fallen to the east of where it was before. About four minutes are required for the earth to turn over sufficiently to bring the sun on the meridian; which makes the solar day longer than the sidereal by four minutes.

Since the earth moves farther in its orbit on some days than on others, the solar days vary in length. To construct clocks to record days of varying length would be both difficult and expensive; and for convenience and economy, the world uses the mean day, which is the average length of all the solar

days for a year. This uniform day greatly simplifies many other processes of civilized life besides that of clock making.

Astronomical observatories have a clock that keeps sidereal time, as for many purposes, time can be more conveniently reckoned by the stars than by the sun. If all our clocks throughout the country should stop some day, we should be compelled to look to the astronomer for the correct time. Every observatory is furnished with reliable star tables, made from the combined observations of astronomers for more than a century. These tell at what moment of time throughout the year sun, moon, and stars appear on the meridian of a place. Then, in the event that the world's timepieces went on a strike, all that astronomers would have to do would be to watch from their observatories for the passage of given stars, or the vernal equinox, across the meridian, and telegraph the recorded time to various points.

Whether our clocks are put completely out of commission or not, they need to be regulated often, and this also is accomplished by the astronomer. In our own country, an electric signal is sent out every day at noon

from the Naval Observatory at Washington, D. C., and is "received by the central New York office of the telegraph company, where it is used to keep correct a very fine clock, which may be called the time standard of the telegraph company. This clock, in turn, has automatic electric connections, by means of which it is made to send out signals over what are called time wires that go all over the city. Jewelers, and others who desire correct time, arrange to have a small electric sounder in their offices connected with the time wires." Thousands of places daily receive the correct time from the Naval Observatory.

Boston, New York, Philadelphia, Baltimore, Washington, New Orleans, and San Francisco also make use of time balls. These are dropped automatically from high towers every day at exact noon. In some British possessions, the time signal — generally the firing of a gun — is usually given at one o'clock in the afternoon instead of at noon.

There are four times in the year when the mean time and the apparent time agree. These are in April, June, September, and December. During the summer months, the

variation between sun time and that of our clocks is slight; but in the early part of November, sun time is faster than clock time, the sun setting more than sixteen minutes before sunset time by the clock. About the middle of February, the sun sets later than clock time by more than fourteen minutes. One has to take account of this difference, called the equation of time, in adjusting sun time with clock time.

That different places should have different times is evident from the fact that the rotation of the earth from west to east causes the sun to rise in the east and to set in the west. This gives Boston sunrise before Chicago, and St. Louis before San Francisco. The eastern of any two cities always has later time than the western. Twenty-four hours are required for the sun to pass over the circle of the earth, or three hundred and sixty degrees; therefore one hour is required for it to pass over fifteen degrees. So if two places are just fifteen degrees apart, they will have a difference of one hour of time. If a place is forty-five degrees west of another, it will have noon three hours after the eastern place.

The situation is complicated when cities are so located that their local times differ by odd numbers of hours, minutes, and seconds. To obviate the perplexing situation caused by the use of local time everywhere, there was introduced in the United States about forty years ago what is known as standard or railroad time. The country is divided into four time zones, Eastern, Central, Mountain, and Pacific. Each zone is fifteen degrees wide, and so arranged that its center is in longitude seventy-five, ninety, one hundred five, or one hundred twenty degrees, making a difference in time of an even number of hours. All places within a given zone have the time of its middle point. The first zone will be five hours behind Greenwich time, and the last one, nine hours; or reckoning from the Washington, D. C., meridian, it will be three hours behind the time of the first zone.

If a person is traveling from New York to Chicago, he knows there will be a difference of one hour in time; so he turns his watch back one hour. This system early proved itself so convenient that standard time has been adopted by all the leading countries of the world.

There is another time problem that mystifies many travelers, and that is the dropping or adding of a day as the one hundred and eightieth meridian is crossed in the Pacific Ocean. Professor Harold Jacoby, of Columbia University, gives such a direct and simple explanation of this proceeding, that we pass it on to you:

"We have seen that of any two places, the eastern always has the later time. Now, imagining that an island is exactly one hundred eighty degrees from Greenwich, we can consider it as being either one hundred eighty degrees east or one hundred eighty degrees west. But if we call it one hundred eighty degrees east, its time will be twelve hours later than Greenwich; and if we call it one hundred eighty degrees west, its time will be twelve hours earlier than Greenwich. Evidently there will be a difference of just twenty-four hours, or one whole day, between these two possible ways of reckoning its time. This circumstance has actually led to considerable confusion in some of the islands of the Pacific Ocean. The navigators who discovered the various islands naturally gave them the date which they brought from Eu-

rope. And as some of these navigators sailed eastward, around the Cape of Good Hope, and others westward, around Cape Horn, the dates they gave to the several islands differed by just one day.

"The state of affairs at the present time has been adjusted by a sort of informal agreement. An arbitrary, irregular line has been drawn on the map near the one hundred eightieth longitude circle; and it has been decided that the islands on the east side of this line shall count their longitudes west from Greenwich, and those west of the line shall count longitude east from Greenwich. Thus Samoa is nearly one hundred eighty degrees west of Greenwich, while the Fiji Islands are nearly one hundred eighty degrees east. Yet the islands are very near each other, though the arbitrary line passes between them. As a result, when it is Sunday in Samoa it is Monday in the Fiji Islands. The arbitrary line described here is sometimes called the International Date Line."

"IT SHALL TEACH THEE"

As one of the heavenly bodies, the earth is not of exceptional interest; but as the home

of man, as a world that has been unmade, as it were, through man's faithless course, and as a world that is to be made new and become the center of interest to the universe of God through Heaven's own intervention, it is of peculiar interest. To the thoughtful student of its varied experience, it reveals lessons of wisdom and encouragement.

THE MOON

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VII

"THE SOUNDLESS WORLD"

"And God made two great lights; the greater light to rule the day, and the lesser light to rule the night." Genesis 1:16.

"There is one glory of the sun, and another glory of the moon." 1 Corinthians 15:41.

"Soon as the evening shades prevail,
The moon takes up the wondrous tale,
And nightly to the listening earth
Proclaims the story of her birth."
—*Addison.*

THE moon seems to be the earth's own particular possession, since it is the nearest heavenly body to the earth, and revolves about it. Our largest telescopes virtually bring it within sixty or eighty miles of us, though its distance from the earth is about two hundred and forty thousand miles. It travels in an elliptical orbit, with the earth at one of the foci, so that it is sometimes twenty-six thousand miles nearer to us than at other times. Though it is near when compared with other heavenly bodies, our most ambitious aviators, maintaining a speed of one hundred and fifty miles an hour day and night, would have to travel for more than two months to reach the moon.

The sun is about four hundred times as far away as the moon, and the nearest star is more than one hundred million times as distant; so it is natural that we should have a neighborly feeling toward our satellite.

The apparent size of the moon is the same as that of the sun, a little more than half a degree in diameter; yet we know the sun's diameter is about four hundred times that of the moon. The fact that the moon is about four hundred times nearer to us than the sun, offsets the sun's greater size, making the two appear almost equal.

One of the first lessons to learn in the study of the heavens is that things are not always as they appear. For example, the sun and the moon seem larger when near the horizon than when nearly overhead. We might reasonably think they would appear larger when near the zenith, for the light coming from them has to travel about four thousand miles less then than when they are near the horizon. The reason why these bodies seem nearer to us in the latter position, is because, in our unconscious comparison, we judge them to be not far away from the trees and other terrestrial objects between us and them.

Seeming nearer, they seem larger. This is only one of many familiar optical illusions.

The moon, as well as the sun, appears red at sunset because blue rays more than the red are intercepted and scattered by the particles of dust and smoke in the air.

> "The disk of Phœbus, when he climbs on high,
> Appears at first but as a bloodshot eye;
> And when his chariot downward 's driven to bed,
> His ball is with the same suffusion red;
> But mounted high on his meridian race,
> All bright he shines, and with a better face."

Astronomers have found little if any evidence of an atmosphere about our satellite. Since air is necessary for the transmission of sound, the moon is therefore called the soundless world. Because of the absence of air, other interesting phenomena also are wanting. "The sky is black and overspread with stars even at midday. There is no twilight, for the sun bursts instantly into day, and, after a fortnight's glare, as suddenly gives place to night; there are no clouds; no winds; no rainbow; no blue sky; no gorgeous tinting of the heavens at sunrise and sunset; no delicate shading; no soft blending of colors, but only sharp outlines of sun and shade."

The moon always keeps the same side toward us as it moves around the earth. It therefore rotates on its axis in the same time that it makes a revolution, which is twenty-seven and a third days. The fact that it rotates will be evident if you will pass an apple round about another object, keeping the same face always toward the central object. The apple must perform a rotation on its axis, else each side would in turn face the center.

Because the moon is slightly tipped on its axis, we sometimes get glimpses beyond each pole; and then, because the moon's velocity in its orbit is not uniform, we sometimes see around the corner, as it were, getting a glimpse of a little part of the half turned from us. But in general, we always see the same side.

As the earth during a sidereal revolution has moved on its orbit, two days more are required for the moon to get in the same position relative to the sun and the earth, thus completing a synodic or lunar month of twenty-nine and a half days. The movement of the moon naturally divides the year into months.

If the earth's diameter were just four times that of the moon, its volume, or size, would

be sixty-four times that of the moon; but since the moon is about two thousand one hundred and sixty miles in diameter, and the earth seven thousand nine hundred and eighteen, only about fifty moons would be required to make a globe equal to the earth.

As the moon revolves around the earth, it passes through its various phases. When it comes between us and the sun, the side of the moon that is lighted up is turned away from us, so we have what is called the new moon; as it proceeds on in its path, we get a glimpse of the lighted side, and we have the crescent moon; then from night to night the crescent broadens until we see half of the lighted side, and the moon is at its first quarter. As it passes on, we see more and more of the lighted side, until the gibbous moon becomes full. It then occupies just the opposite point in the heavens from the sun, and we see the entire bright side. Now, as the moon passes on in her orbit, she changes from full moon to gibbous, third quarter, crescent, and finally is in conjunction with the sun — that is, between the earth and the sun — and we do not see her. For a few days after new moon, we can distinguish the outline of the un-

lighted part, sometimes spoken of as the old moon in the arms of the new. This yellowish light is due to the reflection of the earth's rays upon the moon. It is "earth shine."

The earth would appear to inhabitants on the moon to pass through all phases common to the moon. What a superb body the earth when full would make, as it would equal the light of thirteen full moons! But unfortunately, there seem to be no lunar inhabitants to enjoy this splendid picture.

The crescent moon sometimes stands nearly perpendicular to the horizon; it is then popularly called the "wet" moon, supposedly having spilled upon the earth the water it held. Again the crescent lies almost parallel with the horizon, with the horns up; it is then called the "dry" moon. The position of the crescent has nothing to do with the weather, but it reveals the relative position of moon, sun, and earth.

"The moon and the weather
May change together,
But change of the moon
Does not change the weather;
If we'd no moon at all—
  And that may seem strange—
We still would have weather
  That's subject to change."

Photograph of a Portion of the Moon

The surface of the moon is very broken, being pitted all over with immense craters resembling those of our volcanoes, though incomparably larger. Kepler is credited with the idea that these deep holes were dug by supposed lunar inhabitants, to shield themselves from the burning rays of the long lunar day. Had he known that some of them were more than a hundred miles in diameter and tens of thousands of feet deep, he might have hesitated to attribute to the populace such prodigious industry. To excavate even one of them would be like digging thousands of Panama Canals.

Besides the craters, there are mountain ranges, peaks, clefts, and "rills," which outrival anything of similar nature found on the earth. The moon has its Caucasus, Alps, and Apennine ranges; and its craters are graced with such noted names as Plato, Aristarchus, Copernicus, Tycho, Kepler, and Newton.

Some of the lunar nomenclature is misleading, since the maps show the "Sea of Storms," the "Sea of Showers," the "Sea of Tranquillity," and other similar terms; but these represent great plains instead of oceans and

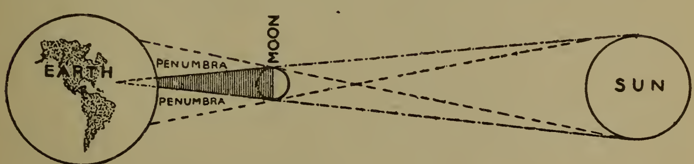
seas. Galileo, who thought them bodies of water, called them "oceans" and "seas," and the terms have been retained, though the moon seems to have no real lakes, rivers, or oceans.

The moon presents an interesting picture through a telescope; and many of its surface irregularities may be observed through an ordinary field or opera glass.

The astronomer now regards the camera as one of his most dependable instruments; for recent photographs of the moon record details that would require an astronomer, using a powerful telescope, years to detect and map.

SOLAR AND LUNAR ECLIPSES

The sun is eclipsed when the moon gets between the earth and the sun, and cuts off



the light of the sun. If it cuts off all the light, or covers the entire face of the sun, there is a total solar eclipse; but if it hides only a part of the sun's disk, then there is a

partial eclipse. If the moon is in the part of its orbit the very farthest from us when an eclipse occurs, the moon will appear smaller, and so will not be able to hide the whole of the sun, but will leave a narrow ring of light around its own dark disk. This is an annular, or ring, eclipse.

Lunar eclipses are caused by the earth coming between the sun and the moon, and cutting off the sun's light from the moon. If the moon passes completely into the long, dark shadow that the earth throws out into space, it is totally eclipsed; for the moon has no light of its own, and can then get none from the sun. If it passes only into the edge of the shadow, or the penumbra, it is partially eclipsed.

The moon, even when completely eclipsed, appears of a reddish color, instead of being black, as we should expect. This is because certain rays of light, as they pass through the earth's atmosphere, are refracted, or bent up, into the umbra, or shadow, giving to the moon this peculiarly interesting tint.

There can be lunar eclipses only at time of full moon, as the moon must be on the opposite side of the earth from the sun to move

into the shadow of the earth. There would be eclipses every month at the full and new moons if the moon's orbit were not inclined to the ecliptic. But since it is, there can be total eclipses only when the moon is at one of the nodes, or points, where its path crosses the ecliptic. Then all three bodies are in direct line. At other times, the moon is either above or else below the plane of the ecliptic.

Astronomers can tell, hundreds of years ahead, just what eclipses are to occur during any given year. Solar eclipses are more numerous than lunar eclipses. There cannot be more than five solar eclipses in any one year, and there cannot be less than two. If five solar eclipses do occur in any one year — which is rarely the case — then there must be two lunar, making seven eclipses during the year.

While solar eclipses occur oftener than lunar, yet many more lunar eclipses are visible at a given place than there are solar eclipses. A total solar eclipse is visible from a given place only once on the average of three hundred and fifty years. The reason for this is that a solar eclipse lasts but six to

eight minutes at the longest, and is visible over a very small area of the earth; while every lunar eclipse lasts from one to four hours, and is visible at the same time over more than a whole hemisphere. In case of a solar eclipse, the moon's shadow thrown upon the earth is seldom more than one hundred miles in width, and hence the region in which the eclipse is total is small. In case of a lunar eclipse, the earth's shadow into which the moon passes is comparatively large.

Anciently, to those not understanding the nature of eclipses, they were omens of evil. Because of this superstition, Columbus used the eclipse of March 1, 1504, to his advantage. His fleet being in great distress from want of supplies, and the inhabitants of the island of Jamaica having refused to assist in providing these, he threatened to deprive them of the light of the moon if they did not render the assistance needed. They paid little heed to his threats; but as the moon began to darken, they quickly vied with one another in bringing supplies.

Mr. Garrett P. Serviss relates an unusually interesting incident connected with the eclipse of the sun of June 28, 1451. It per-

tains to "the celebrated Five Nations, occupying central New York at the time of the arrival of the white men. These Indians had a tradition that a great war between the Mohawks and the Senecas was averted by the interposition of Heaven. Some young Seneca warriors, bent on winning fame for themselves, went, in a time of peace, into the land of the Mohawks and made captive a number of girls who were at work in the cornfields. The captives were taken to Canandaigua. Their arrival caused consternation among the Senecas, whose chiefs knew well the terrible vengeance that the Mohawks would exact. Still, the Senecas also were a proud people; and when swift runners arrived demanding a humiliating submission, the Senecas responded with open defiance, and resolved to meet the Mohawks in battle. A host of Mohawk warriors thirsting for vengeance, hurried on the forest trails to Canandaigua, and the hostile ranks were about to close in deadly contest when one of the Mohawk girls cried out:

"'See! the Great Spirit is angry!'

"She pointed to the sky, and, all eyes following hers, they saw the sun in heaven be-

ginning to darken. Swiftly its light was withdrawn and night fell upon lake and forest. The warriors of both tribes dropped to their knees, and then an aged sachem of the Senecas called for the peace pipe. As it passed from lip to lip, the darkness lightened, the sun slowly reappeared, and in a short time his smiling face was again bent down upon his red children. The captives were surrendered, reparation was made, and the Mohawks, with full quivers, marched back to their valley home."

USES OF THE MOON

The moon was given to rule the night; but it rules the day also, so far as the tides are concerned. If you have been at an ocean beach like Asbury Park or Atlantic City, and watched the tide come in, you know that some stupendous influence was at work. Perhaps you did not give the moon credit for the commotion; but astronomers have found that it is largely responsible for the disturbance, though the sun takes part in the gigantic task of lifting the ocean up out of its bed and returning it thereto twice a day. Were it not that the sun is so far away from the earth, its influence on the tides would be

vastly greater than that of the moon, since it is so much larger.

The tidal waves pass about the earth rapidly, sometimes at the rate of five hundred miles an hour. About every twelve hours and twenty-five minutes, the water begins to flow in toward the shore; it climbs farther and farther up on the beach for about six hours, then it recedes slowly but surely for about the same length of time. Such a strange phenomenon could but set wise men searching for the cause, but the problem baffled them for long years. Finally, after Newton discovered the law of gravitation, the problem of the tides did not have to wait much longer.

This is the accepted solution: The tides are due to the attraction of the sun and moon on the waters of the ocean. The attraction of these bodies pulls the water up and away from the earth on the side next to them; and then, because the earth is nearer than the water on the opposite side of the earth, the earth is pulled away from the water, leaving it heaped up there also. Thus we have high tides on opposite sides of the earth at the same time.

The water does not yield immediately to this gigantic pull; so high tides do not occur when the moon is directly over a place, or on the meridian, but several hours later. The tides may also be impeded by islands and continents deflecting the wave.

When the sun adds its attractive power to that of the moon, as it does at time of new and full moons, we have the spring tides, which are the highest tides. When the moon is at the first or the third quarter, the two forces oppose each other, and then we have the lowest or neap tides. There are other positions of these bodies which also affect the tides.

The height of the tide varies according to the place. In the open sea, the tide may not be noticeable; but where the waves break on the shore or are forced into bays or narrow channels, the water sometimes piles up to a height of sixty or seventy-five feet, as is the case at the Bay of Fundy, Nova Scotia.

Advantage is taken of the rise and fall of the tide, in navigation, and also as water power for mills and factories; but perhaps the chief use of the tides is in their efficacy in purifying land and water.

In some localities, in going up rivers and bays, the tide checks the river water, and causes it to deposit its sediment, thus filling the harbor. Millions of dollars have to be expended annually to counteract this unappreciated work of the tides.

> "How like a queen comes forth the lovely moon,
> Walking in beauty to her midnight throne!"
>
> —*Croly.*

VIII

THE SUPERIOR PLANETS

"The heavens declare the glory of God; and the firmament showeth His handiwork." Psalm 19: 1.

"THE RUDDY WORLD"

NO planet has received more attention from the earth than has Mars. One of our large observatories is said to have taken a hundred thousand photographs of this planet. Its ruddy complexion makes it an attractive object among its lighter-colored associates, though there are several of the brighter stars of a reddish hue, Aldebaran in the constellation Hyades, and Betelgeuse in Orion, being among the number.

To the astronomer, Mars seems the most like our own world of all the planets, though it is not nearly so large, its diameter being but four thousand two hundred miles. Its volume is therefore but one seventh that of the earth. Its gravity is so much less than that of the earth, that a body falls but six feet a second instead of sixteen, and a body weighing one hundred pounds here would weigh but thirty-eight on Mars. Its mean distance from the sun is one hundred forty-

one million five hundred thousand miles, and its average distance from us at opposition is forty-eight million five hundred thousand miles, though at times it comes within thirty-four million miles of the earth.

Mars makes a rotation in twenty-four hours and thirty-seven minutes; and a revolution in six hundred and eighty-seven days, or nearly two years. Its axis is inclined about twenty-seven degrees; so its seasons, astronomically, are quite similar to ours.

The Martians have the advantage over us, in that two moons grace their evening sky. These were discovered in 1877, by Professor Asaph Hall, of the United States Naval Observatory, Washington, D. C. They are so small that it is difficult to measure their diameters. The Lowell Observatory fixes that of Phobos at thirty-six miles, and that of Deimos at ten miles. Their discovery is said to have been as great a feat of telescopic vision "as for a man in Boston to see a tennis ball at Philadelphia." Deimos revolves about Mars in thirty hours and eighteen minutes, while Phobos requires but seven hours and thirty-nine minutes; but Deimos is fourteen thousand six hundred miles from

Mars, while Phobos is but five thousand eight hundred miles.

THE GEOGRAPHY OF MARS

As it seems to have been on our earth before the Flood, so it is on Mars, the land exceeds the water. "Here every continent is an island; there every sea is a lake."

The surface of Mars has received much study; and still astronomers can speak with but little definite knowledge concerning what they observe.

Among the most striking features of this planet are the great white spots at the poles. These are supposed to be extensive snow and ice caps similar to those that cover our own poles; for these are observed to increase during the Martian winter and decrease with the summer, astronomers having watched the apparent melting of the ice. What appear to be continents and islands, seas and lakes, have also been observed; but the "canals" of Mars have been the subject of the most conjecture, and possibly of the most study. "The map of Mars made at the Lowell Observatory at Flagstaff, Arizona, exhibits a bewildering network of canals, connecting small dark spots scattered over the surface. Not in-

frequently half a dozen canals radiate from a single spot, going straight to other spots. Most of the canals choose the shortest path from one spot to another: a few are curved. Some do not run from one small dark spot to another, but connect large dark areas, or go from a small spot to a large area, or occasionally connect two other canals. The small spots are less than one hundred and fifty miles in diameter. The length of the canals ranges from a few hundred to thirty-five hundred miles. Their average breadth is thirty miles. The most mysterious fact about them is that they become double at times, the two new canals being about two hundred miles apart, and veritable twins. Schiaparelli thinks that the doubling may be periodical, and connected in some way with the planet's seasons.

"The canals have naturally been supposed to be waterways. When a polar cap melts, the canals in the neighborhood become darker and wider, and remain dark until the snow stops melting. Then the width of the canals diminishes. These appearances have led Schiaparelli to the conclusion that the canals are natural furrows, through which the water

is carried from the poles equatorward. Mr. Percival Lowell advocates the theory that the canals are strips of vegetation, which are watered by canals too small to be visible to us. A small spot at the junction of several canals is an oasis, according to this view. No satisfactory explanation of the doubling of the canals has been given. The majority of astronomers, while freely admitting the existence of the markings called canals, are inclined to be conservative with reference to any explanation of their nature. It has been aptly said that it is better not to know so much, than to know so many things that are not so."

THE PIGMY WORLDS

A swarm of tiny worlds, one thousand or more in number, each with its own orbit, travels around the sun, between the two superior planets Mars and Jupiter. The largest of the group is less than five hundred miles in diameter, while the majority vary from fifty to ten miles in diameter. The most interesting point about these asteroids, or starlike bodies, is their discovery. Before Kepler's time, astronomers gave credence to


PLANET JUPITER
THE GREAT RED SPOT
THE EARTH DRAWN TO SAME SCALE
JUPITER AS SEEN THROUGH A POWERFUL TEL-
ESCOPE.
HOURLY CHANGES
DUE TO THE RAPID
AXIAL ROTATION
"a" = GREAT RED SPOT
MARS
SHOWING THE
WHITE CAP
COVERING THE
POLE
DIAGRAM BELOW
SHOWING CANALS
ON MARS AS SEEN
WHEN DISCOVERED
- MARS -

a law known as Bode's law. To express this law, they wrote the following series of numbers:

0	3	6	12	24	48	96

Each number, with the exception of the first, is double the one preceding it. Adding four to each of the series, they had—

4	7	10	16	28	52	100

These numbers they found represented quite nearly the distances of the principal planets from the sun, the actual distances being:

M	V	E	M	J	S
3.9	7.2	10	15.2	52.9	95.4

No planet was known to exist between Mars and Jupiter, at the place represented by the number twenty-eight. Astronomers reasoned that if the law is true, there should be a planet at some point between these two bodies. This rule is not exact, but it led to good results; for when astronomers, obedient to this suggestion, turned their telescopes upon the heavens, they found not one planet, but many small planets.

True, they searched in vain from Kepler's time until 1801 before being rewarded by the discovery of the first asteroid; but on the first day of 1801, Ceres was observed. Even then Ceres was discovered by accident, and not as the direct result of Bode's law.

It is said that an extra star was shown on Wollaston's catalogue, due to an error of the press; and the discoverer of Ceres was searching for this extra star when he found Ceres. Pallas was discovered the next year, Juno two years later, and Vesta in 1807. Nearly forty years passed before another planet rewarded the search. Since that time, astronomers have been more successful, discovering them "with almost embarrassing rapidity." The fact that some of these are hardly more than playthings, makes their discovery quite remarkable.

The one-time director of the Ann Arbor, Michigan, observatory, Professor J. C. Watson, had the good fortune to add twenty-two to the list already found. Each newly discovered asteroid entails much labor on the part of astronomers in computing its size, orbit, specific gravity, and other data, without yielding any large returns for this

trouble; so Professor Watson very generously apologized, we might say, for his discoveries, by leaving a fund to care for those he brought to light. Professor J. A. Peters, another American astronomer, has forty-eight of the minor planets to his credit; and Professor Palisa, of Vienna, over eighty.

A name and a number have been given to each of the asteroids, the number being printed in a circle. Why any of them should be afflicted with such names as Xantippe, Vendobona, Mulmosyne, Sophrosyne, Walpurga, is not clear; but the one bearing the name of Chicago commemorates the meeting of the Astronomical Congress at Chicago during the World's Fair.

The fact that a planet moves, while a star does not, or rather, that the stars are too distant for their motion to be easily detected, makes the stars appear as points of light on the exposed photographic plate, while a planet, because of its motion, leaves a streak of light. Many of these asteroids have revealed their presence through this telltale streak.

Though the asteroids are small and apparently unimportant, their origin has given

the sages a problem they cannot solve. Some have suggested that a larger planet must have exploded, but this idea has been shown to be untenable. Some day we may be able to understand their origin, though now even the wisest can only theorize about it.

On one of the asteroids, falling would not be so disastrous an occurrence as it often is on our world; for the force of gravity on Ceres, the largest planetoid, is but one twenty-third that of the earth, so that a body would fall only about seven inches the first second, instead of sixteen feet. Professor H. A. Howe remarks that "in a jumping exhibition, the spectators could eat lunch while waiting for the contestants to come back to terra firma."

"THE BELTED WORLD"

Jupiter, "the belted world," is the giant of our solar system, being larger than all the other planets put together. It is about ninety thousand miles in diameter, which would make it more than thirteen hundred times as large as our earth. If it were as near to us as is the moon, it would preëmpt the space in the sky of one thousand full moons. Yet, if Jupiter were transported to the nearest

star, Alpha Centauri, and became a planetary attendant of that orb, our largest telescopes would seek for it in vain.

Jupiter is about four hundred and eighty-three million miles from the sun. "His apparent movement among the fixed stars is slow and majestic, comporting well with his vast dimensions and the dignity conferred by his nine attendant worlds or moons. He advances through the zodiac at the rate of one sign a year, since it takes him twelve of our years to make a revolution about the sun." But in this time he has traveled at least three billion miles, and has had to prosecute this journey at the rate of five hundred miles a minute. This is no small feat for such a gigantic body. While bowling along in his orbit at this great speed, he rotates on his axis once every nine hours and fifty-five minutes, less than half the time required by the earth to make its rotation. This causes a place on the equator to traverse a distance of four hundred and seventy-three miles a minute, or over twenty-eight thousand miles an hour.

Jupiter, like Venus, is thought to have a dense atmosphere, while that of Mars is rare.

THE PLANET JUPITER

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This planet is one of the most conspicuous and brilliant lights in the starry world. Its brilliance approaches that of Venus, though its light is not so silvery white, having a yellowish tinge. It is five or six times as brilliant as Sirius, the brightest of the stars. When viewed through the telescope, its cloud belts and spots make it an exceptionally interesting object of study. The surface seems banded by parallel brownish or reddish belts, the most conspicuous ones being near the equator. The "belts and spots are supposed to be rifts in the clouds, through which we look down deeper into the atmosphere than elsewhere."

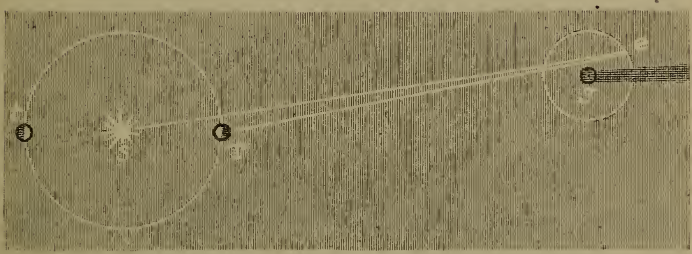
Jupiter has nine moons. Hundreds of years elapsed after Galileo discovered four, before it was known to have others. The remaining five have been discovered since 1892, the ninth having been discovered in September, 1914. Perhaps the end is not yet. The names of the longest known of Jupiter's retinue of satellites are: Io, Europa, Ganymede, and Callisto. Ganymede, the largest, is thirty-seven hundred miles in diameter, nearly the size of Mars. The late Professor Charles Young calls the sixth and seventh

satellites tiny twin moons, which move in nearly circular interlocked orbits, the moons being seven million five hundred thousand miles from Jupiter. The eighth and ninth also seem to be twins, but are at twice the distance from Jupiter as the sixth and seventh. These revolve from east to west instead of in the regular way.

Jupiter casts so long and large a shadow away from the sun that most of the satellites are eclipsed at each revolution. An observer on Jupiter would be able to record thousands of solar and lunar eclipses during one of the planet's years. The eclipses of Jupiter's moons led to the discovery of the velocity of light by a Danish astronomer in 1675. Hitherto light was thought to travel from one point to another instantaneously. If a moon of Jupiter passes behind Jupiter, the light of the sun is cut off from it; so it is invisible to us; it is eclipsed. Astronomers calculated the times of the eclipses; but they found that sometimes the eclipse would occur fifteen minutes later or fifteen minutes earlier than predicted. Roemer, a Danish astronomer, conceived the idea that this was due to the time required for light to travel across the

orbit. Later experiments verified this suggestion.

In the accompanying diagram, "J represents Jupiter; e one of the moons; S the sun; and T and t different positions of the earth in its orbit. When the earth is at T, the eclipse occurs sixteen minutes and thirty-six seconds earlier than at t. That interval



of time is required for the light to travel across the earth's orbit, giving a velocity of about one hundred eighty-six thousand miles a second."

"THE WORLD WITH THE GOLDEN RINGS"

In the days when there was little accurate knowledge of the heavens, and astrology held the people slaves to superstitions of all kinds, the planets were believed to influence the destinies of people. A person born when the

planet Jupiter ruled the heavens was destined to a career of good fortune and honor; while Mars, the god of war, led to martial deeds and military glory. Mercury was thought to rule over the arts, Venus over the affairs of love, and the less brilliant and less known Saturn was supposed to bring misfortune and sorrow. Thus the most interesting of planets never came into its own until after the invention of the telescope, when its wondrous charms were brought to light.

If Jupiter is the king of the planets, Saturn is the queen. With her golden rings, beautifully tinted cloud belts, magnificent retinue of moons, Saturn is unquestionably the most enchanting and interesting object in the sky.

The diameter of Saturn is seventy-four thousand miles, next to that of Jupiter. The planet is seven hundred times as large as the earth, and its mean distance from the sun is eight hundred and eighty-six million miles, one thousand times the diameter of the sun. This makes the planet travel over such an immense orbit that twenty-nine and a half years is consumed in the journey, though it travels at the rate of twenty-one thousand five hun-

dred miles an hour, or three hundred and sixty miles a minute.

If you once locate this yellowish star in the heavens, you will long be able to find it in approximately the same place. Certain almanacs tell in what constellation to look for it during any given month.

While Saturn's year is much longer than ours, its day is shorter; for this great planet is thought to rotate once on its axis every ten hours and fourteen minutes.

The most interesting feature of Saturn is its rings. Galileo was much perplexed by these, as were later astronomers. They could not tell what it was that gave the planet such a variety of phases; for sometimes these rings, if viewed from a certain angle, appeared as a fine line of light passing through the center of the planet at the equator, and extending out for some distance beyond the planet at each side; then again they would disappear altogether, and still again they would appear as broad surfaces about the planet; but at last the Dutch astronomer Huygens in 1655 discovered that what had perplexed and annoyed astronomers was a broad, flat ring nearly parallel to the planet's

equator. Later astronomers found that this ring consisted of three concentric rings instead of one, which are continually whirling around Saturn, but which have the general appearance of one ring passing around the planet. The inner one is six thousand miles from Saturn. It is a dusky, semitransparent ring about eleven thousand miles in width. The second or middle ring is the brightest and broadest of the three, being about eighteen thousand miles wide. The outer one is separated from the middle one by a space or division called Cassini's division, from the Italian astronomer who discovered it. This space measures more than two thousand miles in width. The outer ring is darker than the middle one, but not so dusky as the inner. The diameter of this outer ring is about one hundred and seventy-five thousand miles. It is difficult to appreciate the immense size of this ring trio; but if you think of the outer one as a great boulevard around which an automobile is traveling at the rate of fifty miles an hour, never stopping for rest or repairs, considerably more than a year would be required for it to return to its starting point; and in the meantime, it would have

traveled nearly six hundred thousand miles. In that time, it could have traveled from the earth to the moon and back, and half way to the moon again; or around the earth more than a score of times.

But these rings would hardly serve as a boulevard; for though they are many miles thick, they are not solid or continuous. They are thought to consist of myriads of small moons, closely packed together, each in its own orbit. In the dark rings, they are not so densely packed as in the bright one. An occasional rainbow is always an object of interest to us; what a wonderful spectacle this system of rings, this multitude of moons, must make in the Saturnian sky!

Besides this wealth of associated moons, Saturn has nine separate and distinct satellites. Their distances from the planet vary from many millions of miles to one hundred seventeen thousand; and they perform their revolutions in times varying from eighteen months to less than a day. The ninth satellite is estimated to be eight million miles distant. Its motion is retrograde. Professor W. H. Pickering, of the Harvard Observatory, discovered the ninth satellite in 1898,

and thought he discovered a tenth in 1904, but this supposition has not been fully vindicated. The largest of the moons, Titan, is about the size of Mercury, and it makes a revolution in sixteen days. It can be seen with a telescope of low power. The names of the satellites, given in the order of their distance from Saturn, are: Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Japetus, Phœbe. Mimas, the closest to Saturn, makes a revolution around the planet in twenty-two hours and thirty-seven minutes, while Phœbe requires sixteen months for a revolution.

"THE LONELY WORLDS"

Uranus and Neptune are the only planets with a story of their discovery, the rest having been known from antiquity. Until the eighteenth century, Saturn was supposed to mark the outer boundary of the solar system.

These two planets are called "the lonely worlds," because they are on the outermost edge of our system, Uranus being nearly two billion miles from the sun, and Neptune nearly three billion miles. If you had started six thousand years ago to fly from the sun to Neptune, and had kept up a constant speed, night and day, of a mile a minute,

you would have reached your intended destination; but if you had immediately started on your return trip, even refusing overnight accommodations, you would not by this time have traversed even one fifth of the distance back to Uranus. To complete the return trip would require nearly another five thousand years.

We can better appreciate the story of the discovery of Uranus, the first of the two to be found, if we first sketch briefly the life of the discoverer, William Herschel; and to make that as interesting as it deserves, we shall paraphrase a fascinating sketch given by Herschel's fellow countryman, Sir Robert S. Ball:

William Herschel was born in Hanover, northern Germany. At the age of fourteen, he was made a member of the military band of the Hanoverian Guards. When war broke out between France and England, the French invaded Hanover, as it was then under the English crown. Young Herschel, with the rest of the guards, suffered terribly in one battle. This skirmish providing him with all the war thrills desired, he deserted the army and went to England. He secured a position

as organist of the Octagon Chapel at Bath; and in time, he acquired considerable fame as a music teacher and performer. He was not content, however, to devote all his time to music. He read and studied widely. After mastering higher mathematics, he turned to astronomy. Having his interest aroused in the study of the stars, he felt the need of a telescope, that he might penetrate deeper into the mysteries of the heavens. Telescopes being very expensive, he set about making one. His sister, Caroline, having come to live with him, was of great help to him in his work. So enthusiastic did he become over his telescope, that he would rush home from a concert, and without stopping to remove his laces and other concert apparel, would plunge into the grinding and polishing of mirrors for his telescope.

In the year 1774, he got his first view of the heavens through his completed instrument. We must not imagine that every view through a telescope enriches the observer with some new discovery. Many persons are content to see for themselves the wonders that others have observed; but William Herschel meant to explore the heavens for himself. On the

night of March 13, 1781, he turned his telescope upon Gemini, the Twins, and began to look at one star after another. Stars appear as points of light; and while telescopes make them look brighter, they do not give them an appreciable disk. Herschel observed one that looked larger when viewed through his instrument. He thought he had discovered a comet, for only comets and planets increase in size when viewed through the telescope. He never even supposed there could be another planet; but by further observation, he found that this body moved, and the character of its motion showed that it was not a comet. So he announced the discovery of a planet. To discover a star would not have been counted a great thing, for one might as well talk of discovering a new grain of sand on the seashore. But the addition of another planet to our solar system was a remarkable gift to astronomical science. When George III, king of England, heard of Herschel's achievement, he summoned the astronomer to Windsor. Herschel obeyed, taking his telescope and maps of the heavens with him.

When the news of his discovery was given out, every one began to talk about the organ-

ist at Bath; and, of course, some recalled that he was the one who many years before had deserted from the army. King George heard of this incident; so when Herschel was presented to him, the king suggested that there was an item of business that should receive attention before the discussion of astronomical discoveries. He thereupon handed Herschel a paper, which proved to be a pardon to the deserter, written out by the king himself. The astronomer's surprise was great, but it did not exceed his appreciation of the king's graciousness. Herschel then proceeded to unfold his discovery to the king; and in the evening, he, with his royal host, searched the heavens for its greatest treasures. The ladies of the court heard of the king's interview with the astronomer, and they begged that they also might have a view through the telescope. Herschel was especially anxious for the queen and the ladies of her court to view Saturn. Early in the afternoon, it was evident that the clouds would not permit such a view; but the clever astronomer was not to be outwitted by the clouds. He therefore cut out a picture of Saturn, with its rings and moons; and, tacking it up on a distant garden

fence, and illuminating it with lamps, he was able to satisfy the ladies with an excellent view of the planet.

The result of this visit to the king was an invitation to the astronomer to come to Windsor and devote his entire time to astronomical work, his salary and instruments being provided by the king. As an expression of appreciation to the king, Herschel named his planet Georgium Sidus (the Georgian Star), in honor of the king. But as the other planets were named for heathen deities, the Continental astronomers thought the king would hardly feel at home in such company, so changed the name to Uranus.

This planet is one billion and eight hundred million miles from the sun; and it requires eighty-four years to make a revolution around the sun, and ten hours and fifty minutes to make a rotation on its axis. Uranus is about thirty thousand miles in diameter, which makes it about fifty-four times as large in volume as the earth.

Uranus has four moons, Sir William Herschel having discovered the two brightest, Oberon and Titania. The other two are Ariel and Umbriel. They are from five hundred to

one thousand miles in diameter. In opposition to the rule observed generally throughout the solar system, the moons of Uranus revolve backwards, that is, from east to west; and Uranus itself has been found to rotate in this same direction.

NEPTUNE

While Uranus was a "discovery," Neptune was a mathematical triumph. It came not by accident or from mere observation. Its existence was revealed by Uranus. A French astronomer published tables of the motion of Uranus by which its place at any given time in its orbit could be theoretically predicted. But Uranus refused to follow the path marked out for it. In the course of twenty years, the deviation from the predicted path, though minute in itself, was seriously disturbing to mathematicians. Many questioned whether Newton's law of gravitation was not proving inoperative at this great distance from the sun. Finally the consensus of opinion seemed to be that Newton's law was all right, but that some unknown body, through its attraction for Uranus, was the cause of the discrepancy between the actual and the computed motions of the planet. Ac-

cording to Professor Herbert A. Howe, of Denver University, the story runs as follows:

"John Couch Adams, a tutor in the University of Cambridge, England, grappled with the problem. In October, 1845, he communicated to the astronomer royal of England the elements of the orbit of the suspected planet, together with a prediction of its place in the sky. But the astronomer royal did not regard these investigations of a young and comparatively unknown man as entitled to much confidence. He, however, called the attention of a few of his friends to them, and wrote Adams asking for further information: no reply reached him. He therefore pigeonholed the manuscript. One of the friends wrote to Lassell, who possessed a fine two-foot reflector, which was mounted near Liverpool, begging him to search for the planet. But Lassell was suffering from a sprained ankle, and when he recovered, the letter was nowhere to be found, and the telescopic search was not made.

"Meanwhile Leverrier, a brilliant French astronomer, likewise a young man, had employed his powers upon the same problem. On June 1, 1846, he sent a communication to

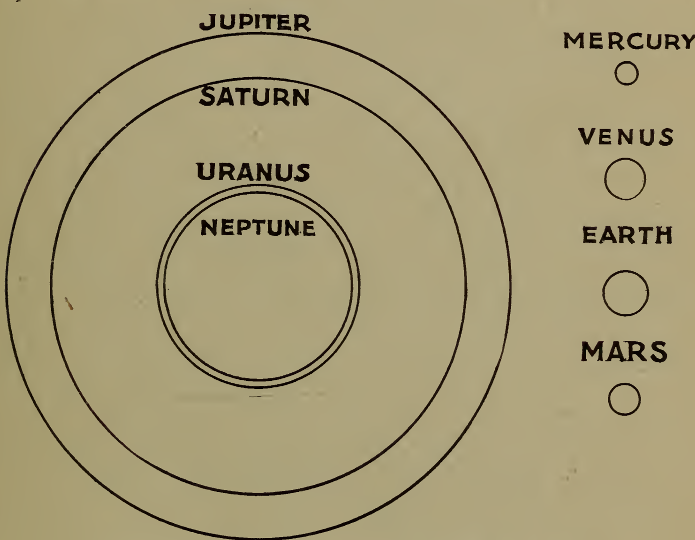
the French Academy of Sciences, giving the direction in which the planet was to be found.

"The English astronomers, finding that Leverrier's results agreed with those of Adams, awoke from their lethargy, and began to bestir themselves. Professor Challis, the astronomer of the University of Cambridge, began a search. Doubting the accuracy of the predictions, he began to map a large area of the sky, hoping by comparison of maps of the same region made on different nights to detect the planet by its change of position if it were really there.

"Sir John Herschel (son of Sir William), in a public address, said concerning the unknown body: 'We see it as Columbus saw America from the coast of Spain. Its movements have been felt, trembling along the far-reaching line of our analysis, with a certainty hardly inferior to that of actual observation.'

"Three times Challis observed the planet, but did not look sharply enough to notice its disk, which was larger than that of the stars. While he was laboriously heaping up observations and neglecting to compare them, the prize of discovery slipped from his grasp.

Leverrier had written to Galle, of Berlin, where excellent star charts were being made, asking him to direct his telescope to a certain point on the ecliptic, and saying that he would find within a degree of that point a new planet, as bright as a star of the ninth



Showing Relative Sizes of the Planets

magnitude and having a perceptible disk. Galle did as he was bidden, and found the planet within half an hour, on September 23, 1846."

The diameter of Neptune is about thirty thousand miles, and its mean distance from

the sun is two billion seven hundred and ninety-two million miles. It has therefore a marvelously long journey to make on its trip around the sun; but by keeping at it and averaging a speed of twelve thousand one hundred and thirty-nine miles an hour, it accomplishes the stupendous task in nearly one hundred and sixty-five years. Its lone satellite performs the same curious feat as do those of Uranus, traveling from east to west instead of from west to east. It is about the same distance from Neptune as our moon is from the earth; but it appears to make a revolution around Neptune in six days.

IX

"THE RUNAWAYS OF THE SKY"

"These wait all upon Thee." Psalm 104: 27.

COMETS

COMETS and meteors may aptly be termed the sky's runaways; for to the casual observer, they go where and when they list, and at whatever speed they elect. But modern astronomers have been able in part to tame these erratics, to solve some of the mysteries enshrouding them, so that now they are registered as reliable, law-abiding members of the celestial economy. Sir Isaac Newton was the first to prove their subservience to the law of gravitation.

Of these two classes of wanderers, comets perhaps merit first and chief attention. These heavenly bodies, generally irregular in form, and often having a long, cloudlike train or tail, flame out in the sky suddenly, and as suddenly disappear. They have fascinated observers for long years.

The word "comet" comes from a word meaning long-haired, the evanescent tail suggesting the flowing locks of a maiden. The

coma is the hazy cloud of luminous matter which is always present in a comet. The nucleus is the bright, starlike point near the center of the coma. In some cases, it is double or multiple; but in other comets, no nucleus is observable. The nucleus and the bright, foggy coma surrounding it form the head of the comet, which may vary in diameter in different comets from forty thousand miles to over a million.

The comet of 1680 had a head estimated to be six hundred thousand miles in diameter; that of 1892 exceeded eight hundred thousand miles; while the comet of 1811, in general the most remarkable comet ever known, and visible for nearly seventeen months, had a head that measured one million two hundred thousand miles in diameter. The tail is a continuation of the coma, a stream of milky light which widens as it recedes from the head. Sometimes a comet has no tail, and again it may have several, these growing or disappearing as the head changes its relation to the sun.

The tail is always directed away from the sun. So a comet, on approaching that body, travels head foremost; but as it recedes, it

goes tail foremost. The way the tail is thought to be formed makes this performance clear; for as the heat of the sun vaporizes the head, the little solid particles thus thrown off are immediately repelled, electrically it seems, and thrown back of the head in a stream constituting the tail. Thus the tail is not permanent, but is constantly being dissipated and renewed. This interesting appendage may increase in length and thickness at the rate of millions of miles a day, attaining, in the end, a fabulous length.

The comet of 1843 had a tail estimated to be one hundred and fifty million miles long; that of 1861 possessed a still longer one. However, "a tail one tenth as long as these is reckoned highly respectable."

A comet is seen only when it is near the sun. The great comet of 1882, bright enough to be seen at noonday, with its magnificent train one hundred million miles in length, came within three hundred thousand miles of the sun's surface. Yet there is no evidence that the warmth of welcome it received on this close visit persuaded it to change its regular schedule of visiting us only once in about eight hundred years.

The number of comets is not known. Kepler thought them as numerous as the fishes of the sea. If they are, they are slow to reveal themselves, for we have records of only about a thousand. The brightest ones were nearly all discovered before the nineteenth century, but there have been three hundred or more discovered since the beginning of that period. The large majority of these, however, are too faint to be seen except through the telescope.

Jean Pons, who lived from 1761-1831, was a doorkeeper at the observatory of Marseilles, France, but later became more famous as an astronomer than Thulis, the director of the observatory, and the one who taught and encouraged the erstwhile doorkeeper. No small degree of the fame of Pons came to him through his success as a comet hunter, he having thirty-seven to his credit. Among those discovered by him was Encke's comet, though it bears the name of the astronomer who determined its period of revolution, rather than that of its discoverer.

Caroline Herschel, sister to Sir William Herschel, discovered eight comets; and Professor E. E. Barnard, an American astrono-

mer of note, discovered sixteen; while Dr. William Brooks, another American astronomer, discovered his twenty-seventh comet on October 20, 1912.

Planets and stars keep their appointed places; but to early observers, comets seemed to dash into our system, unheralded and from any direction, remain a few weeks or months, and then hasten on, perhaps never to return. Yet careful observation has shown that they have regularly appointed paths and that some of them at least do return to us at regular intervals. These, astronomers have had the boldness to appropriate as a part of our solar system. Such is Halley's comet, which visits us about every seventy-six years; Encke's, every three and a half years; Holmes's, with a period of less than seven years; Donati's, one of the finest comets ever seen, with a period of two thousand years; and a number of others.

Halley's comet, which last visited our system in 1910, was the first to be counted as a regular visitor. It is the comet which associated itself with the Norman Conquest of 1066, and received its name from Edmund Halley, the English astronomer who, after

long study of comets in general and of this one in particular, predicted its return in 1758. This was the first prediction ever made of the return of a comet; and fortunately for the astronomical reputation of Mr. Halley, the expected visitor made its appearance on Christmas night of 1758, and continued its course toward the sun until March of the following year, when it started on the return journey. Unfortunately, Mr. Halley was not alive at the time of the fulfillment of his remarkable prophecy. It is interesting to note here that he who first achieved the feat of accurately ascertaining the revolutionary period of a comet, began his astronomical studies in boyhood, sending a paper to the Royal Society before he was twenty years of age. He it was, too, who made, on November 7, 1677, the first complete observation of a transit of Mercury; who catalogued the stars of the Southern Hemisphere from St. Helena; and who was generous enough to give to the world at his own expense the result of a fellow astronomer's observations and deductions,—those of Sir Isaac Newton's "Principia."

Halley's Comet

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After Mr. Halley started the ball rolling, astronomers found that other comets are regular visitors — traveling in closed or elliptical orbits. About seventy-five of these are now known. Even those which seem to move in open curves, parabolas and hyperbolas, are now thought to be really moving in immense elliptical orbits, to traverse which requires thousands of years.

The comet of 1811 is estimated to have a period of three thousand years; and some others are thought to have a much longer period.

There are few speed problems exceeding in interest that of comets. The comet of 1843, with a tail one hundred and fifty million miles long, swept half way around the sun in two hours, which required a speed of more than a million miles an hour. However, this is only about one seven-hundredth as fast as light and electricity travel.

All comets that have periods ranging from three to eight years pass very close to the orbit of Jupiter, and are classified as belonging to "Jupiter's family of comets," which family now numbers about thirty. The other planets are less fortunate, Neptune

being credited with only six, and Saturn and Uranus with two each. Halley's comet forms one of the Neptune group.

Comets have in ages past aroused as much superstition and fear as have eclipses of the sun and moon, which have been known "to stop battles, arrest the march of armies, and dictate treaties," because of the terror they inspired. While the presence of comets once presaged war, pestilence, and death, now these picturesque members of the universe are welcomed as messengers of the Creator's power and love, and not as gloomy portents of His wrath.

> "Stranger of heaven, I bid thee hail!
> Shred from the pall of glory riven,
> That flashest in celestial gale
> Broad pennon of the King of heaven!
>
> "Whate'er portends thy front of fire
> And streaming locks, so lovely pale,
> Or peace to man or judgment dire,
> Stranger of heaven, I bid thee hail!"

METEORS

Meteors are small bodies that are encountered by the earth in its revolution around the sun, and rendered luminous by the resistance of the earth's atmosphere. They appear as shooting stars, fireballs, and me-

teorites. The term "shooting stars" is usually applied to those brilliant points that suddenly dart through the air and leave a fiery train behind, this light being due to the heat generated by the friction of the air as the meteor rapidly penetrates it. Meteors often come in showers, and there may be some seen every night.

Our atmosphere is likened by a noted astronomer to a vast net in which if a small meteor is caught it burns out, thus closing its career forever; but if it succeeds in dashing past our earth without becoming entangled in this net, it may pursue its path unhindered.

Fireballs, or bolides, are similar to shooting stars, only larger, denser, and not so soon consumed in passing through the air. They often explode with a loud noise. While not common, many hundreds have been observed.

The term "meteorite" has been restricted to those meteors which reach the surface of the earth, burying themselves in the ground. The following interesting description of a meteor that exploded in the air is given by Sir Robert Ball, of the University of Cambridge, England:

"There was a celebrated instance in America on the twenty-first of December, 1876, which will give an idea of one of these objects possessing exceptional magnificence. It began in Kansas about seventy-five miles high, and thence it flew for a thousand miles at a speed of ten or fifteen miles a second, until it disappeared somewhere near Lake Ontario.

"Over a certain region between Chicago and St. Louis, the great ball of fire burst into a number of pieces, and formed a cluster of glowing stars that seemed to chase each other over the sky. This cluster must have been about forty miles long and five miles wide; and when the explosion occurred, a most terrific noise was produced, so loud that many thought it was an earthquake. A remarkable circumstance illustrates the tremendous height at which this explosion occurred. The meteor had burst into pieces, the display was all over, and was beginning to be forgotten, and yet nothing had been heard. It was not until a quarter of an hour after the explosion had been seen that a fearful crash was heard at Bloomington. The explosion actually occurred one hundred and eighty miles

from the spot, and as sound takes five seconds to travel a mile, the noise required a quarter of an hour for its journey. What a tremendous noise it must have been!"

Anciently meteors were supposed to be generated in the air by inflammable gases, and were omens of evil. It was the brilliant shower of November 13, 1833, that led to the systematic and earnest study of meteors, which study has resulted in proving "them to be small planetary bodies, practically infinite in numbers and illimitable in the extent and variety of their orbits."

The total number of meteors entering our atmosphere in a single day, meteors that would be visible to the naked eye in the absense of sunlight, moonlight, and clouds, astronomers compute to be at least ten million, "filling the space of the solar system as the air of a summer evening is filled with humming insects." This seems a surprisingly large number; for as single observers, we rarely see any great number during any one evening. But this is not all; we are further told that to this number we should add those visible only through the telescope, which would increase the number manyfold.

Meteors make their appearance in our atmosphere at heights averaging from eighty to forty miles, though they sometimes are first seen at a greater height than eighty miles, and sometimes descend below forty miles. Their velocity can be computed from the length of their course and the duration of their flight; and this is found to vary from seven to seventy miles a second, those of the wonderful shower of November 13, 1833, having a velocity of about forty-four miles a second. Professor Charles Young, onetime professor of astronomy at Princeton University, pronounced this meteoric shower the most remarkable that has ever occurred, "the sky being as full of meteors as it is of snowflakes in time of storm."

Like comets, meteors have been found to travel in closed orbits about the sun. Sometimes they are distributed along the whole orbit; and sometimes they move in swarms, millions of miles long and a hundred thousand miles wide. When the earth comes to the place in its orbit intersected by the path of one of these swarms, and the swarm is there encountered, we have a meteoric shower. This is true of the November Leonids, which

are said to come from a shoal two billion miles long. This shoal completes a circuit around the sun about every thirty-three and a third years. Of this shower, Professor Olmsted, of Yale College, says, "Those who were so fortunate as to witness the exhibition of shooting stars on the morning of November 13, 1833, probably saw the greatest display of celestial fireworks that has ever been since the creation of the world."

The fact that the shower of 1833 was predicted by Bible writers centuries before it occurred, and centuries before man had any real knowledge of falling stars, precludes chance, and shows clearly that the Author of the Bible, the Creator of the heavens and the earth, understands the nature and times of the heavenly bodies, and the laws by which they are directed.

Most of our large museums have handsome specimens of meteorites that have fallen in various parts of the earth. The New York City American Museum of Natural History has the largest mass known. It was brought by Admiral Peary from Greenland, and weighs ninety tons. The sacred black stone of the Caaba, in Mecca, is no doubt a mete-

orite. A stone weighing fourteen hundred pounds, and which fell in Arizona, is in the National Museum at Washington, D. C. One that fell near Buenos Aires was seven and a half feet long, and weighed thirty-three thousand pounds. The dust from the burned-out meteors has been found on Alpine snows, in the depths of the sea, and in other places far from the habitations of men.

One of the latest theories man has devised for the origin of the earth, and one growing in favor with geologists, is that it was made by the in-fall of meteoric matter. At the rate at which this matter falls to the earth at present, one billion years would be required to accumulate a layer one inch thick over the earth's surface. Does it not seem foolish for so-called wise men to give credence to such a slow, laborious, and uncertain process, rather than accept the happy solution given to the problem by the Creator Himself? Through the psalmist He says: "Let all the earth fear the Lord: let all the inhabitants of the world stand in awe of Him. For He spake, and it was done; He commanded, and it stood fast." Psalm 33:8, 9.

Meteorites are of special interest because they give us a glimpse of actual matter outside of our own terrestrial globe. While these stones contain no element unknown to man, they contain some compounds unfamiliar to him. They all contain a peculiar variety of iron, which takes a beautiful polish. Our common iron, when at a high temperature, has the property of absorbing gases, and holding them until reheated to a high degree. Meteoric iron possesses this same property. A lecture on meteors was once delivered in London, while the audience had the interesting experience of sitting under lights that were burning gas taken from a meteorite. Dust from diamonds found in meteoric stones was used at the World's Fair in Chicago, by the Tiffany firm, for polishing other diamonds.

Students of the heavens claim to find a real and close connection between comets and meteors, and that is, that meteors are disintegrated, or broken up, comets; for certain swarms of meteors traverse the path of certain comets, and the composition of meteorites that have been picked up from the earth was found to be the same as that of

certain comets that are counted as lost comets. But this may be only a coincidence.

THE ZODIACAL LIGHT

This is a hazy triangular light, best seen, in north temperate latitudes, projecting up from the horizon in the western sky after sunset from January to April, or in the eastern from September to November before sunrise. It is clearly visible in the tropics throughout the year, and is said to be bright enough to cast a glow on the opposite sky. As a whole, it has the shape of a double convex lens, and is thought to be produced by myriads of meteoric bodies revolving about the sun, forming a sheet somewhat like the rings of Saturn.

THE AURORAS

If you have seen a display of the "northern lights," you have seen one of the most fascinating phenomena of the heavens. Auroral displays are regarded as electrical phenomena, centering about the magnetic poles of the earth. The north magnetic pole, being located near Hudson's Bay and twelve hundred miles from the geographic pole, is nearer the Western Hemisphere than the Eastern;

so the aurora borealis, or northern light, is more frequently observed in the New World than in the Old.

The displays that center about the south magnetic pole are called aurora australis, or southern lights, "aurora" meaning light, and "australis" southern.

Auroral displays at their best are indescribably beautiful and spectacular. Their delicately tinted light sometimes fills the heavens, taking the form of immense folded curtains, arches, streamers, and feathery flames, which are continually changing in form and color, sometimes of a pearly light, then of red, green, pale blue, purple, or gray, or perhaps all commingling in a harmonious whole.

X

"THE JEWELS OF THE SKY"

"And He brought him forth abroad, and said, Look now toward heaven, and tell the stars, if thou be able to number them." Genesis 15: 5.

"He telleth the number of the stars; He calleth them all by their names." Psalm 147: 4.

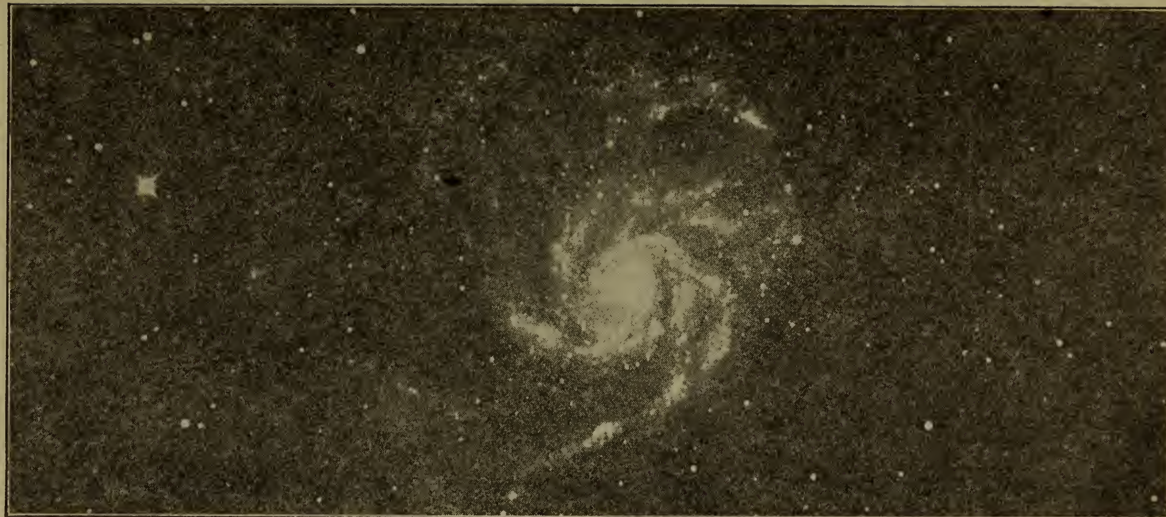
"One star differeth from another star in glory." 1 Corinthians 15: 41.

A STAR is a self-luminous body in space; other heavenly bodies, as planets, shine by reflected light. At times, the celestial sky seems filled with twinkling orbs; but even under the most favorable circumstances, an observer can actually count only two thousand or twenty-five hundred visible at any one time. If he could see the entire celestial sphere as well as he sees that just overhead, he might perhaps discern six thousand stars. Notwithstanding this fact, the stars are innumerable. When the telescope is brought into service, the observer soon finds that the number seen with the naked eye hardly makes a beginning at the celestial count, for that instrument reveals thousands where one can be seen with the naked eye. Then after the power of the telescope is exhausted, the

camera will photograph thousands that are undetected by the telescope alone. Besides the single glittering points that fill the sky, millions upon millions of small stars closely crowded together, along with larger stars and star clusters, are compacted in the Milky Way, that "faint, mysterious river of light which encircles the heavens." A hundred million does not compass the starry host of our sidereal system.

Besides these, there are several hundred thousand of the spiral nebulæ at an appalling distance from us. These are thought by some to be other universes, consisting of stars, star clusters, and nebulæ.

Yet, with all these millions, if not billions, of stars, there is no lack of room in the celestial sphere; for astronomers have found no star within twenty-five trillion miles of us. The immensity of this starless space is better appreciated when we consider that "the earth is to this space as a particle one twentieth of an inch in diameter is to the whole world." It is further claimed that the average distance between the stars is estimated to be three and five tenths sidereal units, or more than six hundred trillion miles, one sidereal unit of



A Spiral Nebula

space being two hundred thousand times our distance from the sun.

Think then of the extent of the universe that harbors no less than one hundred million stars! Surely we exclaim with Richter's angel: "End there is none of the universe of God!"

Each of the stars is supposed to be the center of a magnificent solar system, many of which systems far transcend in magnitude and importance our own. From Neptune as an observatory, the stars would appear but little if any brighter, since two billion, seven hundred and ninety-two million miles, the distance of Neptune from our sun, is of small moment when compared with stellar distances; for the nearest of the stars is estimated to be at least twenty-five trillions of miles distant. From this star, Alpha Centauri, our sun would appear about as the North Star does to us, and none of its worlds or their satellites could be seen. If ten feet were taken to represent the distance of Neptune from the sun, then eighty-nine thousand, five hundred and forty-five feet, or nearly seventeen miles, would represent the distance of Alpha Centauri from us.

The brightest stars have special names; but astronomers identify the stars of a constellation by the Greek letters of the alphabet, according to their order of position or degree of brightness, the brightest star being known as Alpha, the first letter; the second brightest as Beta, the second letter; and the third, Gamma; and so on down the alphabet. The name of the constellation is also added, as Alpha Orionis, the astronomer's name for Betelgeuse (bet-el-guz), the brightest star of Orion. Where there are a large number of stars in a constellation, Roman letters and Arabic numerals are called into service, as 61 Cygni, of the constellation Cygnus. More than a million stars have been catalogued, that is, named, numbered, and definitely located.

> "The stars and all the flowers that sleep below them
> Are his who learns to name them and to know them."

DISTANCE OF THE STARS FROM US

Because of their great distance, we never see the real surface of the stars, but see only the light sent out from them years before. At the incomprehensible speed with which light travels, one hundred and eighty-six

Andromeda Nebula

thousand, three hundred miles a second, it is estimated that centuries and even millenniums are required for the light from some of the stars to reach us. If a star is one light year distant from us, it is 5,881,807,810,620 miles distant. This immense distance, then, is the measuring rod, the "yardstick," for measuring stellar distances; but there is no star even this near to us. According to this unit of measurement, four and a third years are required for the light of Alpha Centauri, the very nearest star, to reach the earth; forty-seven years for the light of Polaris, the North Star; more than nine years for the light of Sirius; three hundred and thirty years for that of Rigel; one hundred and sixty years for that of Arcturus; and three hundred and seventy for that of Antares. Some portions of the Milky Way are computed to be one hundred thousand light years from us, and the nebulæ of Andromeda six hundred thousand light years distant, while other nebulæ are placed at still greater distances. What do these figures mean? Professor David Todd, of the Amherst Observatory, in an attempt to help us comprehend their meaning, says:

"While one is taking two ordinary steps, at an average walking pace, light will travel a distance equal to eight times round the world, nearly two hundred thousand miles. Now, to realize in some sense the enormous distance of the nearest fixed star from our earth, open a Webster's International Dictionary, which contains over two thousand pages of three columns each, or the equivalent. Begin to read as rapidly as you can, and imagine a ray of light to have just left the nearest fixed star at the instant you begin. By the time you have finished a single page, the star's light will have sped onward toward the earth no less than one hundred million miles. Imagine that you could keep right on reading, tirelessly and without ceasing, day and night, just as light itself travels — how many pages would you have read when the ray of light from Alpha Centauri, the nearest fixed star, had reached the earth? You would have read it completely through,— not once, or twice, but nearly a hundred times. So enormously distant is this nearest of the stars that, if it were blotted out of existence this present moment, it would continue to shine in its accustomed place for more than four

years to come. And other stars whose distances have been measured are a hundredfold more remote."

Surely we exclaim with Eliphaz of old, "Behold the height of the stars, how high they are!" Job 22:12.

HOW DISTANCE OF STARS IS DETERMINED

Astronomers determine the approximate distance of the stars from us by obtaining their parallax. Hold your index finger about one foot from your eye. Close one eye, and notice where the finger, as seen by the other eye, registers itself on the wall you face. Without changing the position of the finger, look at it with the other eye. The difference in the apparent positions of the finger as seen with the two eyes, is its angle of parallax. The farther you hold the finger from you, the less the parallax. By locating a star when looking at it on a given day, then six months later, when the earth is in the exact opposite part of the orbit, making a distance of one hundred and eighty-six million miles between the two positions, the star's parallax is obtained. From this parallax and the one hundred and eighty-six million miles, astrono-

mers, by the use of trigonometry, can determine the distance of the star. It was in 1838 that the parallax of a star was first determined; and up to 1917, the parallax of less than three hundred stars had been found, most of these orbs being too far away to show parallax. But in 1917, a new method of determining parallax was discovered at the Mt. Wilson Observatory. Wonderful results have been achieved by this method, so that now the approximate parallax, at least, of about one thousand stars is known.

MOTION OF THE "FIXED STARS"

The term "fixed stars" is common; but this term is allowable only as one refers to the fact that the stars apparently maintain from year to year the same relative positions. However, they are far from stationary, as they revolve around their centers of gravity at speeds sometimes far exceeding those of the planets of our system, and far more swiftly than the swiftest cannon ball, which is but little less than half a mile a second. The average star speed is given by Kapteyn as twenty-six miles a second, though some stars have a velocity of more than two hun-

dred miles a second. Yet, at the average speed of twenty-six miles a second, many thousands of years would be required for a star to cover one sidereal unit of space.

The Lord said to Job, "Canst thou guide Arcturus with his sons?" Astronomers have ascertained that this giant of the sky, at least a million times larger than our own sun, flies through space with its retinue of worlds, or "sons," at the rate of more than nine hundred thousand miles an hour, or at nearly nine times the speed of Mercury, or fourteen times that of the earth. Surely only Omnipotent power can "guide Arcturus with his sons" on their mad rush through space.

Our own sun, with its coterie of worlds keeping close to it, is said to sweep onward through space at the rate of four hundred million miles a year. Its course is directed toward a point in Hercules.

Again, the Lord asks Job, "Canst thou . . . loose the bands of Orion?" By the revolution of the stars and their consequent change of position, the belt or "bands of Orion" may ultimately glide apart or loosen; but man is powerless to make the change.

In speaking of this mysterious and interesting triplet, Hugh McMillan says:

"Can man, whose breath is in his nostrils, and who is crushed before the moth, unclasp that brilliant starry bracelet which God's own hand has fastened on the dusky arm of night? Can man separate these stars from one another, or alter their relative positions in the smallest degree? What is it that controls all their movements, and keeps them united together in their peculiar form? It is the force of gravitation, which is not a mere mechanical agency, unoriginated and uncontrolled, but the delegated power of the Almighty—the will of Him who has the keys of the universe, and 'shutteth, and no man openeth; and openeth, and no man shutteth.' How sublime the thought, that the same Power which binds the starry bands of Orion, keeps together the particles of the common stone by the wayside,—that those mighty masses are controlled by the same almighty influence, which regulates the falling of the snowflake and the gentle breath of summer, that directs the motions of the minutest animalcule, and weaves the attenuated line of the gossamer!"

While from year to year the great sidereal system presents an unchanged appearance to the casual observer, the close student of the sky notes significant changes; but these are so small in most cases that they are recorded in terms of centuries instead of years. For example, Halley found, in 1718, that Arcturus had moved toward the south nearly a whole degree since the time of Hipparchus, who lived from 180-110 B. C., and Sirius about half as much. A star's change of position in the sky, or "its drift with respect to a fixed system of reference lines," is known as its proper motion, but this is not the star's real motion.

Halley was the first person to detect this annual drift of the stars. A star may be moving directly toward or away from the earth, at great speed, yet it will show no proper motion; it will appear to be fixed on the celestial sphere. But a star moving across our view will reveal a proper motion, dependent upon its velocity, or real motion, and its distance from us. The greater the distance of a star, other things not being considered, the less its proper motion. The brightest stars all reveal a proper motion;

and on an average, their proper motion is larger than that of the faint stars. However, the star with the very largest proper motion that had been observed up to 1898 is 1830 Groombridge, a star of the eighth magnitude. It has an annual drift of seven seconds of arc (a second of arc being 1/3600 of a degree), so was called the "runaway" star. At this rate, two hundred and seventy years, it is estimated, would be required for it to change its apparent position by a space equal to the apparent diameter of the moon, or a little more than half a degree. The star that superseded 1830 Groombridge in 1898 has a proper motion of eight and seven tenths seconds annually.

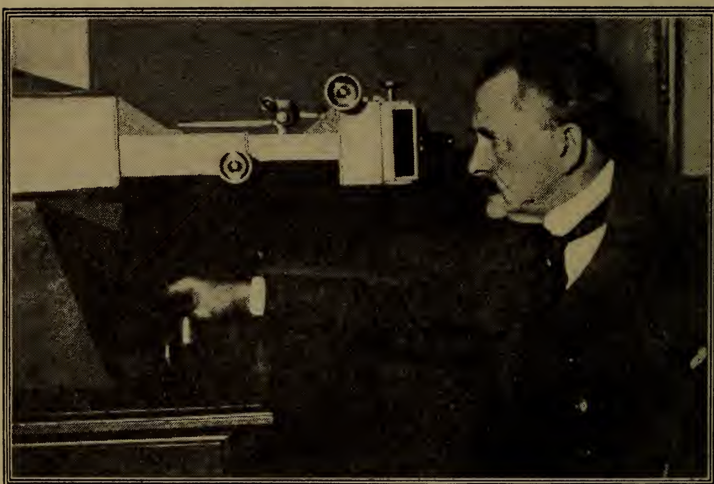
There are said to be less than two hundred stars that have a proper motion of as much as one second of arc a year. This distance would be approximately one eighteen thousandth of the space between the Pointers, the space between these two stars of the Large Dipper being about five degrees. Astronomers claim that stars with a proper motion of five seconds of arc a century are quite uniformly scattered over the sky, while those with a less proper motion than five

seconds a century cluster in the region of the Milky Way.

SIZE OF THE STARS

The immense distance of most of the stars from the earth precludes astronomers from ascertaining their size; but there are a few that have yielded interesting returns. Algol, in the constellation Perseus, is thought to have a diameter of more than a million miles; and it has a companion, or dark body, about the size of our sun, revolving about it at a distance of three million and five hundred thousand miles. Arcturus is estimated to have a diameter of eighty-six million miles, about one hundred times that of our own sun. Just about the close of 1920, on December 13, the diameter of Betelgeuse, the reddish first magnitude star in Orion, was obtained by Professor Michelson, of Chicago University, and Professor Pease, of the Mt. Wilson Observatory. By use of the interferometer in connection with the high-powered telescope, the angular diameter of Betelgeuse was approximately determined. This feat is said to correspond to ascertaining the apparent angular diameter of a sphere one foot in diameter and eight hundred and fifty miles

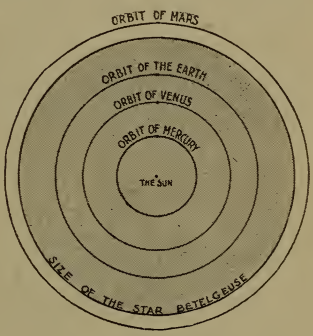
distant; and therefore we need not wonder that astronomers are willing to admit that the determined result is not without probable error, possibly a fifty per cent error. But even then, Betelgeuse would exceed all other stars or planets that had been measured up



Professor Albert A. Michelson

to that time, and would be large enough to fill the orbit of Mars. The determination of the diameter of Betelgeuse marked one of the greatest of astronomical achievements. This angular diameter was found to be forty-six thousandths of a second of arc. This was the angle formed between two rays of

light starting from opposite sides of the great star and coming together in the telescope. With this angle, the rays would be so "nearly parallel that they would not show a spread of a hair's breadth in two hundred and fifty yards, and we should have to travel back along the rays for a distance of over seventy miles before we should reach a separation of one inch. Of course, the farther we trace these rays, the greater the separation, until eventually we arrive at their source, where, of course, their separation equals the diameter of the star. Hence if we know the distance of the star from our telescope, we can determine the diameter."



The unit of measurement employed in this determination was half a wave length of light. The average length of a wave of light is two one-hundred-thousandths of an inch. One writer, in an effort to give a concrete conception of this unit, says that a very fine human hair measures perhaps two one-thousandths of an inch in thickness; if we

were to split that hair into one hundred slivers, each sliver would equal the length of a light wave. One half of this equals the unit of measurement employed in finding the diameter of Betelgeuse. This was therefore one one-hundredth of half a hair's breadth.

The distance of Betelgeuse is reckoned as about two hundred light years, or more than a quadrillion miles from us. The working out of this problem gives Betelgeuse a diameter of nearly three hundred million miles. If the distance of Betelgeuse is not exact, the diameter as given is not altogether correct.

Betelgeuse was found to have a parallax of sixteen thousandths of a second, which would give it a diameter of two hundred and seventy-three million miles. If this parallax is too large by half, then the diameter of the star is computed to be more than five hundred million miles. If the parallax is twenty-four thousandths of a second, the diameter equals one hundred and eighty-two million miles. Betelgeuse would be no pigmy sun, even if the least of these determinations should prove to be the one most nearly correct.

Less than a year after the announcement of Professor Pease concerning the diameter

of Betelgeuse, he determined the diameter of Antares, the reddish first magnitude star in the constellation Scorpio. Its apparent diameter, obtained with the Michelson interferometer, is thirty-nine thousandths of a second of arc, a little less than that of Betelgeuse. Since Antares is given as three hundred and seventy light years distant from us, its diameter is computed to be four hundred and twenty million miles, more than twice that of the earth's orbit.

STARS CLASSIFIED ACCORDING TO BRIGHTNESS

Early astronomers noted the varying brightness of stars, and arbitrarily classified them according to their brightness. An attempt was later made to establish a definite ratio between the magnitudes, making those of the first magnitude about two and one half times as bright as those of the second, and similarly those of the second about two and one half times those of the third, and so on up to and beyond the fifteenth magnitude. Few can see, with the unaided eye, stars fainter than those of the sixth magnitude. The approximate ratio of a first magnitude star to one of the twentieth magnitude is as thirty-seven million to one.

Even this classification was not sufficiently accurate for the present-day astronomer; so he makes use of fractions, and of zero and negative magnitudes. The invention of the photometer enabled astronomers to measure the light accurately, and therefore permitted a more exact classification.

The need of a more scientific classification is readily apparent. Pollux and Regulus are stars of the first magnitude; but there are first magnitude stars two and a half times as bright as these, so they are said to be of "zero" magnitude. Capella and Rigel are examples of this magnitude. But there are stars much brighter than any of the zero magnitude. Sirius, one of these, is thirteen times as bright as Regulus, a first magnitude star, and several times brighter than Capella, a "zero" star. So the magnitude of Sirius is said to be negative; that is, it surpasses the zero brightness. From Sirius, which is fifty-one trillion miles from us, our sun would appear to be only a third magnitude star; still the light of six billion stars like Sirius would be required to give us the brilliancy of a bright June day. The average distance of a first magnitude star from us is given as one

hundred and sixty quadrillion miles, while a star of the eighth magnitude is estimated to be more than twenty times as far away. There follows a list of our twenty brightest stars, with their magnitudes as given in "Descriptive Astronomy," by Professor Moulton:

Sirius (sir'i-us)	—1.6
Canopus (ka-nō'pus)	—0.9
Alpha Centauri (al'fa sen-tau'rī)	0.1
Vega (vē'ga)	0.1
Capella (ka-pel'a)	0.2
Arcturus (ärk-tū'rus)	0.2
Rigel (rī'jel)	0.3
Procyon (prō'si-on)	0.5
Achernar (a'ker-när)	0.6
Beta Centauri (bē'ta sen-tau'rī)	0.9
Altair (al-tä'ir)	0.9
Betelgeuse (bet-el-guz')	0.9
Alpha Crucis (al'fa crū'sis)	1.1
Aldebaran (al-deb'a-ran)	1.1
Spica (spī'ka)	1.2
Pollux (pol'uks)	1.2
Antares (an-tā'rēz)	1.2
Fomalhaut (fō'mal-hawt)	1.3
Deneb (den'eb)	1.3
Regulus (reg'u-lus)	1.3

VARIABLE STARS

There are stars which do not always manifest the same degree of brightness; some fluctuate regularly and some irregularly. Algol, in Perseus, is a variable star. For about two and a half days, it is a second magnitude star, when it suddenly decreases, and in three and

a half hours becomes a fourth magnitude star. It then rekindles and becomes as bright as ever. The fluctuations of Mira, in the constellation Cetus, are equally interesting. It is of the second magnitude for about fifteen days, then for three months it decreases in brilliancy until it becomes invisible to the naked eye. This period of darkness lasts five months, when it gradually brightens until it regains its usual brilliancy. Mira's fluctuations were observed as early as the sixteenth century.

More than four thousand variables are known. The reason for this change in brightness is not fully understood; but it is thought to be due, in a certain type of variables at least, to a dark body, a planet perhaps, revolving about the star, and thus in certain positions partially, if not altogether, cutting off the star's light. The periods of variables range from a few hours to more than a year, six hundred and ten days. There is a star in Cygnus, 65 Cygni, which represents a triple system of great interest, with a period of three hours and twenty-five minutes, the shortest known period. The diameter of the

brightest star of the trio is computed to be over five million miles.

Stars differ not only in brightness, but in the color of the light they emit, "every tint that blooms in the flowers of summer flaming out in the sky at night."

Antares, Aldebaran, Betelgeuse, and Arcturus shine with a reddish light. There are telescopic stars which give forth a blood-red light. Vega is bluish, as are many of those in the Milky Way. Sirius and Procyon are white, while Capella shines with a yellowish or creamy white light. It is in the double or multiple stars that the greatest display of color is seen.

DOUBLE OR MULTIPLE STARS

A double or multiple star appears as a single star until separated into two or more by the telescope. Some of the double or multiple stars are only optically so; that is, they seem to be near each other, but are not. They lie in the same straight line from us, but may be at immense distances from each other and bear no special relation to each other. But practically all of the more than twenty thousand double and multiple stars

known are physically related; that is, they have a common center of gravity around which they revolve, and thus appear to revolve around each other, as Tennyson says:

> "Those double stars
> Whereof the one more bright
> Is circled by the other."

Professor W. W. Campbell, of the Lick Observatory, estimates that one out of every four stars is revealed to be a binary by the spectroscope. If this is even approximately true, the thousands of known doubles or multiples are only a hint of the real number that exist.

The members of such systems are often of different colors, a green star having perhaps a blood-red companion, an orange star a blue companion, while a yellow star may have a purple one associated with it. A triple star in Andromeda consists of an orange-red sun and two of an emerald green color.

Rigel, in Orion, is a noted double star. So also is Polaris, one component being a yellowish star a little below second magnitude, and the other a white just below the ninth magnitude. Capella and Sirius are both double stars. The companion of Sirius is a star of

the tenth magnitude and revolves around Sirius in about fifty years. This companion made its presence known by its pull on Sirius, sixteen years before it was seen through a telescope.

NEBULÆ

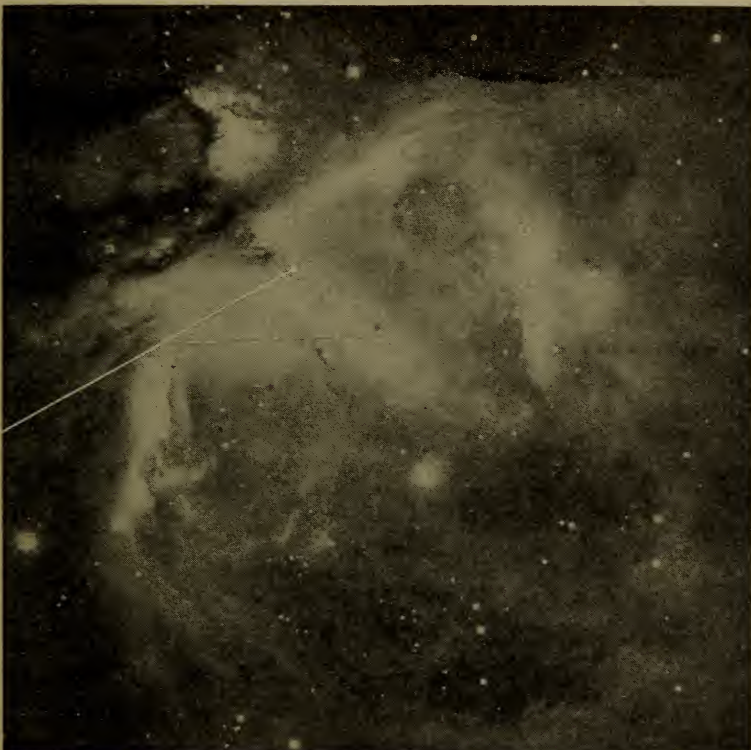
The word "nebula" comes from the Latin word for cloud. The dictionary defines a nebula as "a faint, cloudlike, self-luminous mass of attenuated matter situated far outside of the solar system;" but astronomically not all nebulæ are now considered self-luminous. In 1771, an astronomer listed one hundred and three of these cloud masses. Sir William Herschel increased the number to over twenty-five hundred; and his son Sir John Herschel catalogued and described nearly four thousand nebulæ. Other astronomers all the way along have added to this number, until it is asserted that not less than a half million nebulæ are within the power of the Lick telescope.

These are of various shapes and sizes, and travel at varying velocities, some having a velocity of more than two hundred miles a second. According to some authorities, nebulæ are classified as extended, spiral, and

planetary. The spiral are numbered by the hundred thousand, and are far more numerous than either of the others. They are regarded as the largest and most mysterious class of objects in the celestial sphere, though some of the planetary nebulæ are said to occupy a space many times the size of our solar system. The minimum distance of the spiral nebulæ from us is estimated to be the appalling distance of one million light years; or 1,000,000 x 186,000 x 60 x 60 x 24 x 365 miles. The study of the spiral nebulæ, which are called "island universes," has greatly enlarged the astronomer's conception of the extent of space. They are thought by some astronomers to be outside of our immense sidereal or starry system, and are believed to represent new stellar universes, perhaps much exceeding our own in extent and interest.

Among the most interesting nebulæ of our stellar system are the Great Nebula of Orion, the Spiral Nebula of Canes Venatici, the Annular Nebula of Lyra, and the Nebula of Andromeda. The Owl Nebula is in the Great Bear, about midway between the Pointers.

In brilliancy and variety of detail, the nebula of Orion exceeds all others known to astronomers. This, you will recall, is the nebula surrounding the middle star of the sword of Orion, which is a multiple star with four of its stars arranged in the form of a trapezium.



THE GREAT NEBULA OF ORION

While the Dutch astronomer Huygens discovered this nebula in 1656, and it has since been studied through our greatest telescopes, yet not until it traced its own story in a flood of glorious light upon the photographic plate did astronomers altogether appreciate this wonderful phenomenon. They now observe that "the whole constellation of Orion is enmeshed with mysterious loops and laces of nebulous cloud." Sir John Herschel says, "It is remarkable, however, that within the area of the trapezium no nebula exists," neither is there sun, planet, or satellite.

Surrounding the trapezium is the brightest part of the nebula. Huygens said that so bright was this nebula, that in contrast the heavens about seemed "quite black, the effect being that of an opening in the sky, through which a brighter region was visible."

In ordinary telescopes, the nebula seems to be a flat surface; but photographs reveal the central region of the space within the quadrilateral to be the mouth of a colossal cave—"the open space of Orion." This yawning abyss is thought to have a diameter of sixteen trillion and seven hundred fifty billion miles. If so, since the diameter of the orbit of the

earth "is one hundred and eighty-six million miles, ninety thousand of these orbits, side by side, forming one straight line of rings, could enter the appalling chasm." The diameter of the orbit of Neptune is five billion, five hundred and eighty-four million miles; but we are assured that three thousand circles of this diameter placed side by side, "could pass into the open space in Orion and not touch its starry lighted sides." And its depth may greatly exceed its width.

Finite mind cannot grasp the immensity of these figures; yet this is only a very small part of the universe of God. Surely we can say with another: "Lo, these are only the outlying borders of His works. What a whisper of a word we hear of Him! The thunder of His power who can comprehend?"

In the year 1848, there were shown to Mrs. E. G. White some of the events connected with the Saviour's return to earth. In recounting these, she wrote:

"Dark, heavy clouds came up and clashed against each other. The atmosphere parted and rolled back. Then we could look up through the open space in Orion, whence

came the voice of God. The holy city will come down through that open space."

In view, then, of the fact that the voice of God sounds forth through this space, and through it the city of God comes down to earth, may it not be that this open space is but the great corridor to the throne of God, and that beyond it are the everlasting gates that were lifted up to receive the King of Glory, and that will again open before Him as He comes to receive His own?

XI

THE CONSTELLATIONS

"The sad and solemn night
  Hath yet her multitude of cheerful fires;
The glorious host of light
  Walk the dark hemisphere till she retires;
All through her silent watches, gliding slow,
  Her constellations come, and climb the
      heavens, and go."
—*William Cullen Bryant.*

THE constellations are largely fanciful groups of stars, conceived and named by the ancients. The less fantastic groups, such as the two dippers, are noted by all observers. For convenience in the study of the stars, the old grouping is retained.

The zodiac is a belt in the celestial sphere which extends eight degrees on each side of the ecliptic. It encircles the sky "like the colored band on a croquet ball." Within this belt move the sun, the moon, and all the planets. It is divided into twelve equal divisions called signs. The signs of the zodiac, beginning with the vernal equinox, are: Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces. The objects represented by these in their order are: the ram, bull, twins, crab,

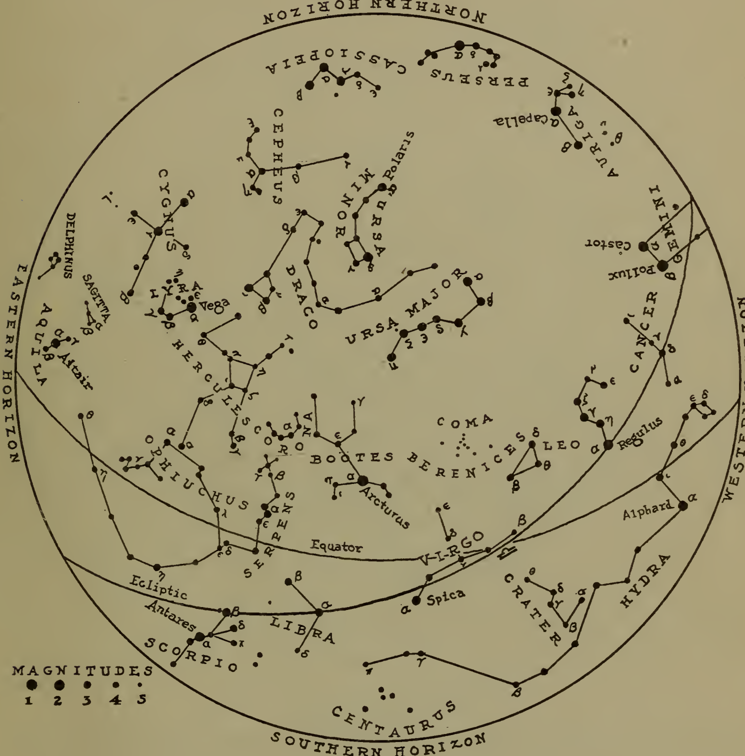
lion, virgin, scales, scorpion, archer, goat, water bearer, and fishes. The signs are represented by appropriate symbols. In the entrance lobby of the Congressional Library at

CONSTELLATIONS IN THE SPRING SKY — FEBRUARY, MARCH, APRIL

Month	1st	15th
February	12 Midn.	11 P. M.
March	10 P. M.	9 P. M.
April	8 P. M.	7 P. M.

Washington, D. C., the symbols for these signs are inlaid in the floor.

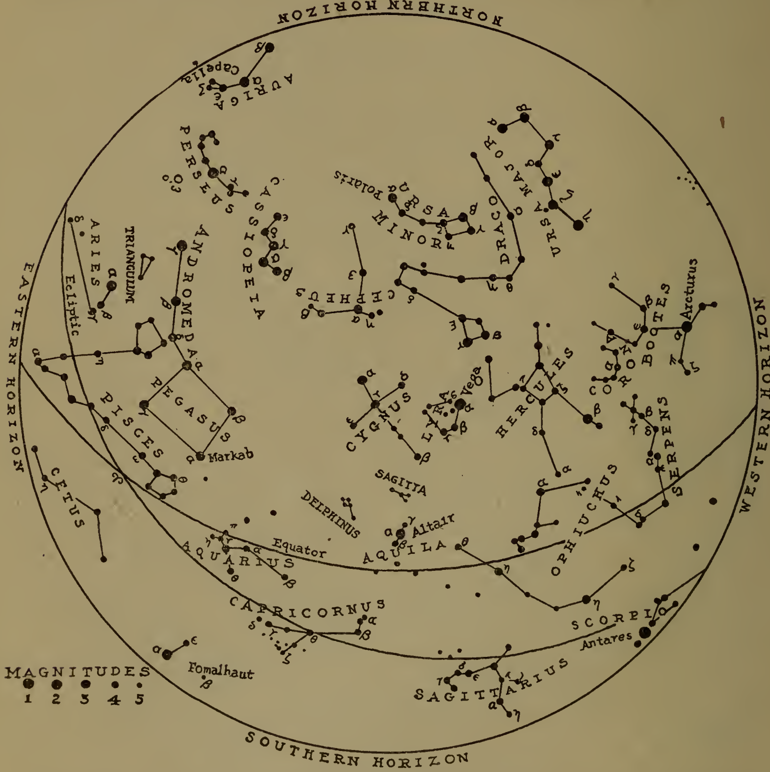
The signs bear the names of the constellations with which they coincided when first



Constellations in the Summer Sky — May, June, July

Month	1st	15th
May	12 Midn.	11 P. M.
June	10 P. M.	9 P. M.
July	8 P. M.	

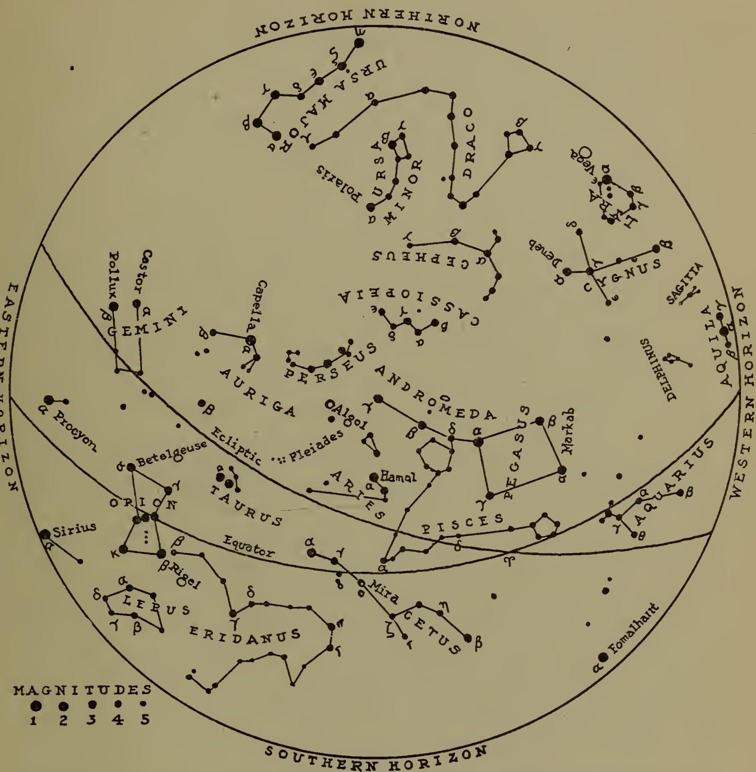
named, the sign Aries being in the constellation Aries, Pisces in Pisces, and so on through the list. The equinoctial points have



CONSTELLATIONS IN THE AUTUMN SKY — AUGUST, SEPTEMBER, OCTOBER

Month	1st	15th
August	12 Midn.	11 P. M.
September	10 P. M.	9 P. M.
October	8 P. M.	7 P. M.
November	6 P. M.	5 P. M.

annually retrograded, or slipped back, on the ecliptic about fifty seconds; so that now the sign Aries is in the constellation Pisces, and



CONSTELLATIONS IN THE WINTER SKY — NOVEMBER, DECEMBER, JANUARY

Month	1st	15th
November	12 Midn.	11 P. M.
December	10 P. M.	9 P. M.
January	8 P. M.	7 P. M.
February	6 P. M.	5 P. M.

Pisces in Aquarius. The following stanza alludes to this precession of the equinoxes, and traces the sun in its path through the zodiac:

> "This is the way the spring begins:
> First Aries, then Taurus, then the Heavenly Twins.
> The first summer sign is the one we call Cancer;
> The next two to Leo and Virgo will answer.
> Then autumn brings Libra and bright Scorpio,
> And next Sagittarius, with his strong bow.
> Capricornus then ushers the winter in,
> And near old Aquarius the year we begin,
> Pisces comes next, and then winter is done;
> And with Aries's approach, a new spring is begun.
> These are the *signs;* but bear this in mind:
> The sun lags in one constellation behind.
> When his place is Aries, we'll find him in Pisces;
> When in Taurus he should be, in Aries he stays.
> If Gemini's his place, and to find him our wish is,
> We must look back in Taurus to see his
> bright rays.
> And so through the year, whatever his place is,
> The bright group behind is the one that he graces."

Recognition of the constellations of the same name as these signs, enables one to locate the ecliptic at any time of year. From a few nights' observation, one may familiarize one's self with these constellations, and with the ecliptic and the equinoctial, the bases of important celestial measurements.

One of the most interesting of the northern polar constellations, those which are always above the horizon in north temperate latitudes, is Ursa Major, the Great Bear. The

principal stars of this group form the Big Dipper. In England, the Big Dipper is known as Charles's Wain or the Plow. The two stars at the front of the bowl of the Dipper are called the "Pointers," because a line drawn through them and continued northward to about five times the distance between the two stars, or twenty-five degrees, passes very near the North Star. The polestar, or Polaris, is at the end of the tail of the Small Bear, or Ursa Minor. A group of seven stars in this constellation forms the Little Dipper, the polestar marking the end of the handle. The star Zeta, or Mizar, at the bend of the handle of the Large Dipper, is double, being composed of a white star and a green one.

Draco, the Dragon, is a long, twisting line of stars, stretching between the Large and the Small Dipper, nearly encircling the latter, and finally reaching out its head, a quadrilateral group of stars, almost to the body of Hercules.

> "Here the vast Dragon twines
> Between the Bears and like a river winds."

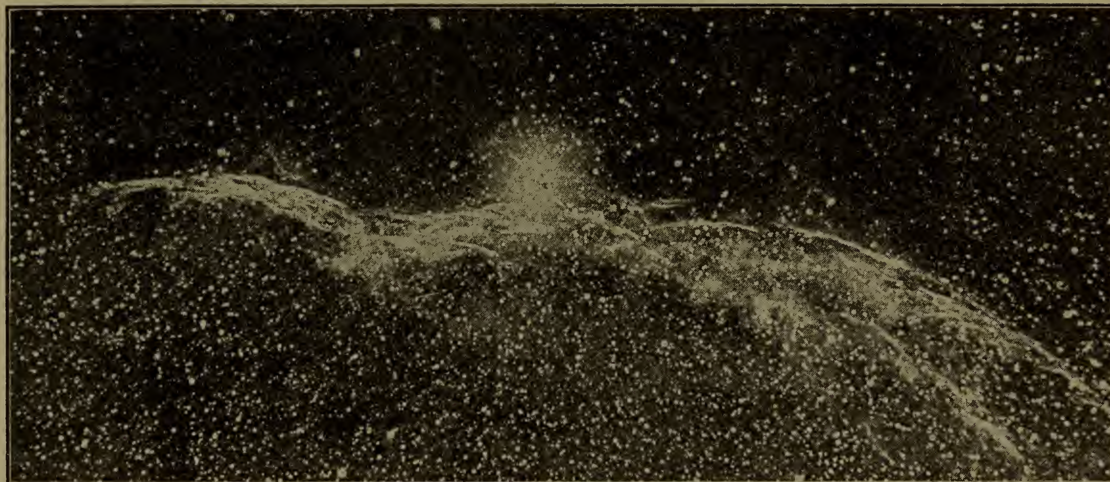
On the opposite side of the polestar from the Large Dipper, and at about the same

distance from the pole as the Dipper, is the constellation Cassiopeia (kas-i-o-pe′ya), the principal stars of which, six in number, form an inverted chair with a crooked back; or if the faint star of the front edge of the seat is omitted, a spread-out W appears. One can easily find this constellation on any clear night. The Greek legend represents Cassiopeia as a queen seated in her throne with King Cepheus at her right, Perseus, her son-in-law, on her left, and Andromeda, her daughter, above her. These are all names of constellations easily discerned, as one searches the northern sky.

Perseus is a group of stars lying between Auriga and Pegasus, and very near to Cassiopeia. The variable star Algol is in this constellation.

Cepheus is on the opposite side of the pole from Ursa Major, and it has two bright stars that make almost as good "pointers" as the two in that constellation. They are nearer the pole and farther apart.

A line drawn through the last two stars of the handle of the Great Dipper and prolonged away from the pole passes near Arcturus, at the point of the tail of a huge



Cygnus, the Swan

kite-shaped figure, the constellation Boötes, the Bear Keeper. Close to Boötes is Corona, the Crown, a group of six stars arranged in a semicircle.

Cygnus, the Swan, is not far from the head of Draco. The principal stars of Cygnus form a large cross, known as the Northern Cross, the upright piece of which lies in the Milky Way. One of the small stars of this group, 61 Cygni, is the nearest to us of all the stars in the Northern Hemisphere, being only five hundred and fifty thousand times farther away from us than is our sun, or fifty-one trillion miles. Deneb is the last star in the upright piece of the Cross, above the arms. It forms a large triangle with Vega in Lyra and Altair in Aquila.

> "Yonder goes Cygnus, the Swan, flying southward,—
> Sign of the Cross, and of Christ unto me."
>
> —*Smith.*

Andromeda, and Pegasus, the Winged Horse, are found by drawing a line from Polaris through Cassiopeia and prolonging it an equal distance beyond Cassiopeia. The three chief stars of Pegasus, together with Alpha Andromeda, form a large, rude square. Just beneath this square is the constellation

Pisces. One of the fishes is marked by a six-sided polygon, south of one side of the square of Pegasus, and the other is opposite the adjoining side of the square, next to Andromeda. The two fishes are tied together by a long double line of stars, rather faint but discernible. Pisces is an interesting constellation, from the fact that in it is the point where the sun crosses the celestial equator on its way north in the spring. This point is known as the vernal equinox, and is the celestial Greenwich, the point from which a star's right ascension is measured. It can be located by drawing a line from Polaris through Beta Cassiopeia, and on past Alpherat, the star in the square of Pegasus that is common to Andromeda, and continuing it to meet Pisces. Andromeda includes the row of bright stars extending from one corner of the square of Pegasus, with a small triangle near by.

Lyra, the Harp, which contains the beautiful star Vega, is not far to the northeast of Boötes. To find the friendly twinkler, Vega, draw a line from the star at the junction of the bowl and the handle of the Dipper to Polaris, or the North Star. Then from Po-

laris draw a line at right angles to the first line nearly forty degrees in length on the same side of the Dipper from which the handle projects, and it will point out a small triangle with Vega at one of the angles. This is the most brilliant star in the northern heavens. It lies near the Milky Way.

Not far from Vega, and just across the Milky Way, lies the constellation Aquila. Altair, the brilliant first magnitude star, is the middle star of a line of three stars. Altair is found to be approaching the earth at the rate of more than eight hundred million miles a year.

Auriga, the Charioteer, may be found by drawing a line from Polaris at right angles to the line from the Pointers to the pole, and running in an opposite direction from the handle to the Dipper; or starting "at the star which marks the bottom of the Dipper on the handle side and running thence about halfway between the two Pointers, for a distance of about fifty degrees, or to the first bright star, you will reach Capella," the brightest star of Auriga, and also the second brightest of the northern heavens. The principal stars of Auriga are in the form of a large irregular

five-sided figure. Capella marks one of the corners of the pentagon. At nine o'clock on a January night, you will be able to see this beautiful star almost overhead. Near Capella, in a side of the pentagon, is a small triangle of three stars, called the Kids, which will aid in identifying Auriga.

A line from Polaris through Cassiopeia and between Perseus and Andromeda, when prolonged, pierces a small triangle, which marks the head of Aries, the Ram. You will want to become familiar with Aries, "the prince of the zodiac," as it will aid in locating the ecliptic.

Taurus, the Bull, contains two interesting groups of stars. The V-shaped group in the bull's head is Hyades, and the bright reddish star at one corner of the opening is Aldebaran. You will not regret heeding Mrs. Sigourney's suggestion:

> "Go forth at night,
> And talk with Aldebaran, where
> he flames
> In the cold forehead of the winter
> sky."

In the fore shoulder of Taurus lies the beautiful cluster known as the Pleiades, or "the seven stars, glittering and quivering

NEBULÆ IN THE PLEIADES

(218)

with radiance in the amethystine ether like a breastplate of jewels — the Urim and Thummim of the Eternal." The telescope and the photographic plate have revealed more than seven thousand stars in this group; but only six are clearly visible to the naked eye. Some persons, however, are able to see from ten to fourteen stars. William Cullen Bryant alludes to the Pleiades in the lines:

> "The group of sister stars which mothers love
> To show their wondering babes, the gentle seven."

A line drawn from the Pleiades through Aldebaran in Hyades and continued but a short distance cuts into Orion, the mighty hunter, the most magnificent constellation in the heavens, and easily discerned as one looks toward the south on a midwinter evening. Orion is marked by four bright stars forming a parallelogram. Since he is represented as facing Taurus, the Bull, Betelgeuse, a red star of the first magnitude, marks the right shoulder of the mighty hunter, and Bellatrix (be-la′triks) the left shoulder. Rigel, a bluish-white star of the first magnitude, marks the left foot, and Saiph the right knee. Near the center of the quadrilateral lie three

bright stars, which constitute the bands, or belt, of Orion.

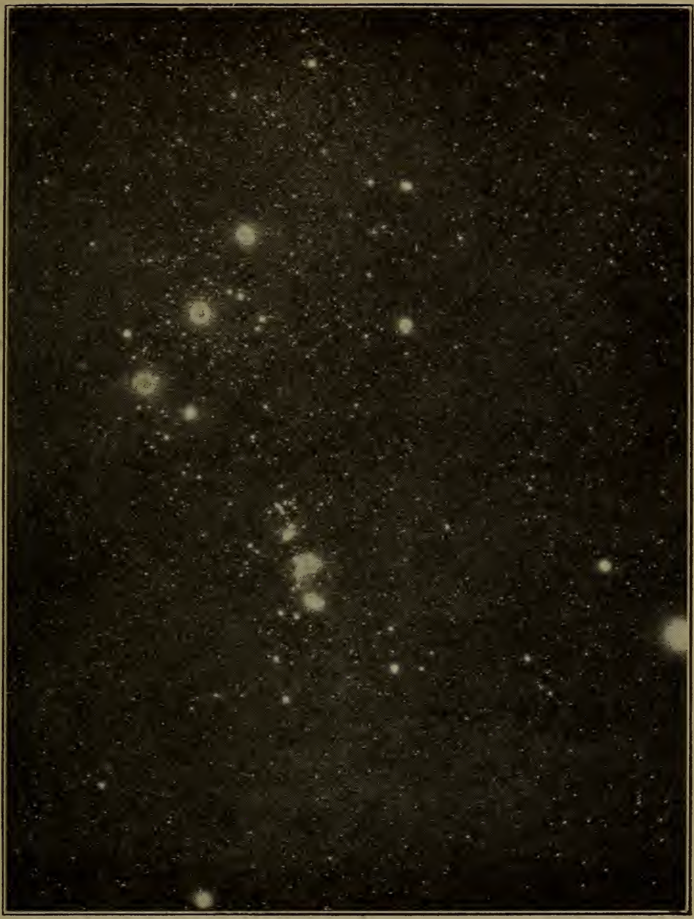
Extending southward from the belt is an irregular line of three stars, which marks the giant's sword. The middle one of this group is surrounded by a hazy, cloudlike mass known as the Great Nebula of Orion. The telescope reveals this star, Theta Orionis, to be a multiple star, the four principal stars being arranged in the form of an irregular quadrilateral, with two others near and still others scattered throughout the great nebulous cloud. Within this quadrilateral is the "open space" of Orion.

> "A single misty star,
> Which is the second in a line of stars
> That seem a sword beneath a belt of three,
> I never gazed upon it but I dreamt
> Of some vast charm concluded in that star
> To make fame nothing."
>
> —*Tennyson.*

Just below Orion are four stars forming a beautiful figure called Lepus, the Hare; and just south of it is Columba, Noah's Dove.

> "Below Orion's feet the Hare
> Is chased eternally; behind him
> Sirius ever speeds as in pursuit."
>
> —*Aratus.*

A line drawn through the belt of Orion and continued for a short distance passes through



THE SWORD AND BELT OF ORION

The belt is composed of the three second magnitude stars standing obliquely on the left. The three smaller stars below in a nearly vertical line form the sword. The center light of the sword is the nebula.

Sirius, the brightest star of the heavens. Sirius is known as the Dog Star, because it is in the constellation Canis Major, or Great Dog. You will want to know this brightest star in the sky, and one of our nearest stars; so to make sure you have Sirius, draw a line from Aldebaran in Hyades through Bellatrix in Orion, and extend it until it comes near to the first bright sparkler. This will be the Dog Star. It will be on the meridian, up about twenty degrees, in the southern sky, about nine o'clock in February.

Sirius is best observed in the early evening during the winter months. On Thanksgiving night, he makes his debut above the eastern horizon about nine o'clock. He is one of the latest of a retinue of brilliant stars to make their appearance; Vega, Altair, Capella, Aldebaran, Betelgeuse, Rigel, Castor, Pollux, and Procyon, having preceded him. Month after month, he comes up a little earlier each succeeding day; so that by March and April, he is at his best, being high in the heavens in the early evening, though not more than one third of the distance to the zenith.

> "The fiery Sirius alters hue
> And bickers into red and emerald."
>
> —*Tennyson.*

Just to the north and east of Sirius, and almost in a line with Betelgeuse in the right shoulder of Orion, is Canis Minor, the Little Dog. The brightest star of this group is Procyon. It is not more than sixty-five trillions of miles from us; so its light reaches us in a little more than ten years.

> "Let Procyon join to Betelgeuse,
> And pass a line afar
> To reach the point where Sirius glows,
> The most conspicuous star,
> Then will the eye delighted view
> A figure fine and vast;
> Its span is equilateral,
> Triangular its cast."

Northeast of Orion lies the beautiful constellation Gemini (jem'i-ni), or the Twins. Its principal stars are arranged in three rows, with two stars in each row. The stars in the first row are much brighter than those to the west, and are nearer together. These two stars are Castor and Pollux. During May and the first half of June, these stars hang high in the northwestern heavens. A straight line drawn through the stars of the handle of the Big Dipper, excepting the last star of the handle, and on through the lower front star of the bowl, and on a distance beyond, will pass midway between Castor and Pollux.

These are the stars the apostle Paul mentioned in relating some of the incidents of his voyage to Rome. They were supposed to influence navigation propitiously. Pollux is a triple star, its components showing orange, gray, and lilac colors.

Leo, the Lion, is an interesting constellation, with the principal stars in the shoulder of the lion in the form of a sickle. It adorns the evening sky from New Year's day until June or July. A line drawn through the Pointers away from the polestar, and continued about forty degrees, will meet Leo. Look for this interesting constellation to the left and just a little below Gemini, not far from the Big Dipper on the side away from the pole. Regulus is the bright star in the end of the handle of the sickle, and is sometimes called the Lion's heart. It is not far from Procyon.

"From the time it first attracts our attention until Arcturus and Vega come, Regulus is the chief ornament of the eastern skies and shines like a veritable diamond of the highest quality, fit to be set in the jeweled hilt of sword or scimitar of fine Damascus steel rather than the handle of a homely garden

implement." Regulus forms a large triangle with Spica and Arcturus at the base.

It is from Leo that the shooting stars in the 1833 shower seemed to radiate, "even as a fig tree casteth her untimely figs, when she is shaken of a mighty wind."

Scorpio is one of the constellations of the zodiac. If you want to see Scorpio, with its ruddy jewel Antares, at its best, explore the southern sky just before bedtime on the longest day of the year. At other times, draw a line connecting Vega with Altair, and from Vega draw a line at right angles to this line away from Cygnus, or the Northern Cross. Extend this line to meet the first bright reddish star, or to a distance of about twelve times the distance between the Pointers, and you will have Antares, that great sun which is three hundred and seventy light years distant from us, and which so recently has been computed to have a diameter of four hundred and thirty million miles. Antares throws such a soft, friendly light out upon the sky, that it readily wins the admiration of star lovers.

Other constellations, such as Aquarius, the Water Bearer; Cancer, the Crab; Capri-

cornus, the Goat; Cetus, the Whale; Corvus, the Crow; Crater, the Cup; Hercules; Hydra, the Snake; Libra, the Scales; Lupus, the Wolf; Sagittarius, the Archer; and Virgo, the Virgin, are all worth your making their acquaintance. Spica, a bewitching star of the first magnitude, is in Virgo. It stands alone, there being no other very bright star within thirty degrees of it. Spica, Arcturus, Denebola, and Cor Caroli form the celebrated "Diamond of Virgo."

If we lived far south of the equator, we should see a few constellations that we cannot see in this latitude. As the southern polar constellations came into view, we should lose sight of our northern circumpolar friends.

While there is no south polar star, there is a Southern Cross that is about thirty degrees from the south pole. This consists chiefly of four bright stars; but much has been written about their splendor.

Centaurus is another constellation well known to us, because its brightest star, Alpha Centauri, has the distinction of being the nearest to the earth of all the millions of stars. That we in this latitude cannot see Alpha Centauri is to be regretted. If any

of you ever pay a visit to the tropics, do not forget, in your sight-seeing, to "lift your eyes on high;" for there Alpha Centauri reveals itself; so does Canopus, a star that vies with Sirius in brilliancy; and Alpha Crucis, Achernar, and Beta Centauri.

Canopus belongs to the constellation Argo Navis, or the Southern Ship. This may be seen by observers in our most southern states. Canopus, like Alpha Centauri, was worshiped by the ancient Egyptians.

Why not make friends with the stars? "There is pleasure in the pathless woods;" but there is greater pleasure in exploring "the infinite meadows of heaven." If you cultivate close acquaintanceship with the jewels of the sky, you can never be alone, whether in China or at home; for in general, the same stars will greet you in whatever land you may be.

"To the astronomer, the fixed stars are immovable boundary stones by which he determines the courses of the wandering heavenly bodies. To the geographer, they are the signal stations according to which he surveys the chart of the earth by the heavens. To the mariner, they are the lights that direct him

over the dark paths of the seas. To the hunter, the herdsman, the wanderer, they are a clock. To the farmer, they are a calendar. The historian finds in them many a memorable event in the oldest Grecian history; and every person of sensibility receives from them an impulse to worship, meditation, and hope."

PRONUNCIATION OF NAMES OF CONSTELLATIONS

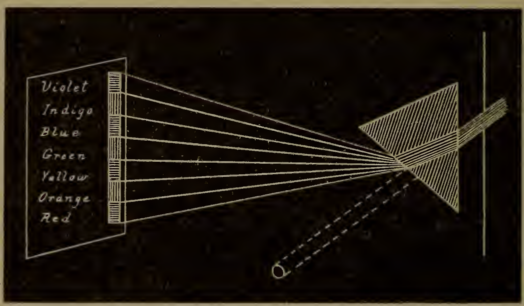
Andromeda (an-drom′e-da)
Aquarius (a-kwā′rĭ-us)
Aquila (ăk′wĭ-la)
Argo Navis (är′gō nā′vis)
Aries (ā′rĭ-ēz)
Auriga (au-rī′ga)
Boötes (bō-ō′tez)
Camelopardus (kam-el-o-par′dus)
Cancer (kan′ser)
Canes Venatici (kā′nēz ve-nat′i-sī)
Canis Major (kā′nis mā′jor)
Canis Minor (kā′nis mī′nor)
Capricornus (kăp-ri-kor′nus)
Cassiopeia (kas-si-ō-pē′ya)
Centaurus (sen-taw′rus)
Cepheus (sē′fūs)
Cetus (sē′tus)
Columba (kō-lum′ba)
Coma Berenices (kō′ma bĕr-e-nī′sēz)
Corona Borealis (ko-rō′na bō-re-ā′lis)
Corvus (kor′vus)
Crater (krā′ter)
Cygnus (sig′nus)
Delphinus (del-fī′nus)
Draco (drā′kō)
Equuleus (e-kwoo′le-us)
Eridanus (e-rĭd′a-nus)
Gemini (jem′ĭ-nī)
Hercules (hur′kū-lēz)
Hydra (hy′dra)
Lacerta (la-sur′ta)
Leo (lē′ō)
Leo Minor (lē′ō mī′nor)
Lepus (lē′pus)
Libra (lī′bra)
Lupus (lū′pus)
Lynx (links)
Lyra (ly′ra)
Monoceros (mō-nos′e-ros)
Ophiuchus (of-i-ū′kus)
Orion (ō-rī′on)
Pegasus (peg′ă-sus)
Perseus (pur′sūs)
Pisces (pĭs′ēz)
Piscis Australis (pis′is aus-trā′lis)
Sagitta (sa-jit′ta)
Sagittarius (saj-i-tā′ri-us)
Scorpio (skor′pĭ-ō)
Sculptor (skulp′tor)
Scutum (skū′tum)
Serpens (ser′penz)
Sextans (seks′tanz)
Taurus (taw′rus)
Triangulum (tri-ang′gu-lum)
Ursa Major (ur′sa mā-jor)
Ursa Minor (ur′sa mī-nor)
Virgo (vir′gō)
Vulpecula (vul-pek′u-la)

XII

SPECTROSCOPE AND SPECTRA

"By what way is the light parted?" Job 38: 24.

SIR ISAAC NEWTON (1642-1727 A. D.) was the first to answer the foregoing question, though since the flood, the rainbow—that "child of sun and shower"—has stood as a silent witness to the fact that light



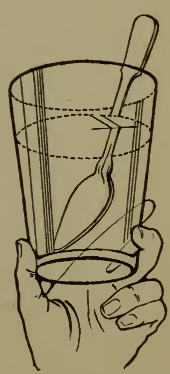
THE SPECTRUM

can be parted, or separated into various colors. So has every tint of sky, earth, or sea. Before Newton's discovery that sunlight consists of many rays, each capable of producing a color all its own, it was thought that the colors revealed by passing white light through a prism were the result of an actual change made in the light by the prism, and not a

mere spreading out, or separation, of component colors.

Newton found that the colors were due to the fact that the rays composing white light were refracted or bent at different angles, and thus were separated. If you place a pencil obliquely in a glass of clear water, and look at the glass from the side, the pencil will appear to be bent. This is because a ray of light in passing from one medium into another of different density, is bent, or refracted. If it passes into a denser medium, it is bent toward the perpendicular to the surface that separates the two media; and if it passes into a rarer, or less dense medium, as from water into air, it is bent away from the perpendicular.

The well-known but interesting experiment of placing a coin on the bottom of a basin so as to be just hidden by the edge, and then pouring water into the basin until the coin becomes visible from the same point, is another illustration of this principle of refraction.



Since one sees the coin in the direction of the extended bent portion of the ray of light,

the coin seems to have been lifted up or shifted from its real position to another one, whence it becomes visible.

When light passes from the air into the dense glass of the prism, the rays are refracted, or bent, the shorter waves being bent more than the long ones; hence the colors are

dispersed, or separated. The band of colors obtained by the refraction, or dispersion, is called a spectrum, which is naught "but a slice of a rainbow cut crosswise." The spectrum obtained when the sunlight is analyzed is known as the solar spectrum. Each kind of light has its own particular spectrum. It might be well for the reader to throw a spectrum on the wall by means of a prism, and study it more carefully, perhaps, than he has heretofore.

The generally accepted theory concerning light is that it is radiant energy transmitted

by the ether that is supposed to fill all space, which energy is in the form of waves capable of producing the sensation of sight. These waves, or vibrations, vary in length and frequency, according to the color produced when they strike the eye, the particular color of a light wave depending upon the length of the wave, just as the pitch of a tone depends upon the length of the sound wave.

Red light has the longest wave length of any visible color, and its rate of vibration is the slowest; while violet has the shortest wave length, and its rate of vibration is the greatest. The length of the red wave is one thirty-thousandth of an inch; and it is produced by more than four hundred billion ether waves beating upon the retina of the eye a second.

The violet wave is only one sixty-thousandth of an inch in length, and it is produced by more than seven hundred billion waves a second meeting the eye. The red wave is at one end of the solar spectrum, and the violet at the other end. All other visible rays lie between these two colors. Invisible waves have been discovered below the red and above the violet; these are known as the infra-red and the ultra-violet.

Sir William Herschel was the first to discover that the spectrum extends beyond visible limits, he having discovered infra-red waves. Hitherto the thought had not been conceived that there could be invisible rays of light; but after the existence of infra-red waves, some many times as long as the red, was confirmed, it was not long before the ultra-violet were found. The visible spectrum extends from seventy-six hundred to thirty-nine hundred units; but by various means, emission spectra have been traced between the limits of three million one hundred and thirty units.

The X ray, which has attracted so much attention since its discovery in 1895, has recently been found to be one of the invisible rays of light some distance beyond the violet wave. Its wave length is given as about one ten-thousandth of that of the violet wave, and its frequency of vibration ten thousand times that of the violet wave. The wireless wave is a very long wave compared with light waves. Some of these reach the length of many thousand feet; but they travel with the speed of light.

The rays toward the red end of the spectrum and below it are chiefly heat rays, while those toward the violet end and beyond are chiefly chemical, or actinic, rays. The latter take our photographs, change the starch in unripened fruits and grains to sugar, and work other equally interesting and effective wonders.

The spectroscope, the instrument used in analyzing light, giving us the various spectra, has been of incalculable aid to the astronomer. It was produced in 1859, and it has proved itself a worthy helpmate of the telescope. It has revealed so many interesting things, that it is worth the study required to understand its structure and workings. In its simplest form, the spectroscope consists of two small telescopes, with a glass prism mounted between their object glasses. The beam of light enters through a narrow slit in the first telescope. Its rays are rendered parallel by the object glass in this instrument. The parallel rays then pass through the prism, where they are bent, or refracted, at different angles, and hence pass out of the prism at different angles, spreading out the colors into a spectrum as the observer sees them through the second

telescope. This is what the raindrops in the air do to the sunlight to give us the magnificent rainbow spectrum.

For astronomical work, a train of prisms, or a "diffraction grating," may be used in the place of a single prism. This grating, a piece of glass or speculum metal, is ruled with from five thousand to twenty thousand straight, equidistant lines, which spread or disperse the light as does the prism. A mother-of-pearl shell beautifully illustrates diffraction; for the overlapping of the layers diffracts, or disperses, the light as does the grating, and gives us the shell's characteristic display of color. At the Mt. Wilson Observatory, a solar spectrum seventy feet long may be obtained. In this, the sodium lines, which are barely separated in the ordinary spectrum, appear more than one inch apart.

The following facts and laws have been evolved through the study of the spectra of various kinds and combinations of light:

A continuous spectrum consists of an unbroken band of colors; while a discontinuous spectrum is a spectrum crossed by dark or light lines. All luminous solids and liquids give continuous spectra; so do glowing gases

under high pressure. The spectrum of a gas jet, kerosene lamp, or candle is continuous because of the small solid particles of glowing carbon in the flame.

Glowing rarefied vapors and gases give discontinuous spectra. These are made up of bright lines. The spectrum of sodium vapor is characterized by two bright yellow lines, called the D lines, so near together that they are often treated as one line. A lithium vapor spectrum contains, among many others, a splendid red line; hydrogen, three lines, one red, one greenish blue, and the other dark blue.

If a light from a glowing, or incandescent, solid or liquid passes through a gas at a temperature lower than that of the incandescent body, the gas absorbs rays of the same degree of refrangibility as that of the rays which constitute its own spectrum. This is what is known as a dark-lined spectrum, and the dark lines occupy the same position in the spectrum that the bright lines of the gas itself would occupy.

For example, the sodium spectrum consists of two bright yellow lines on a comparatively dark background. Now if the solar spectrum — that is, the spectrum of sunlight —

is placed just below the sodium spectrum, a dark line will be found in the solar spectrum where the yellow lines are in the sodium spectrum. This shows that as the light of the photosphere passed through the chromosphere of the sun, part of the light was absorbed by the chromosphere; and since it was that part corresponding to the yellow lines, evidently there must be glowing sodium in the chromosphere of the sun, for "vapors of different substances absorb or quench the very same rays that they are capable of emitting when self-luminous."

The spectrum of iron vapor contains thousands of bright lines; and these have their dark counterparts in the solar spectrum, showing the presence of iron in the sun.

When the uses of the spectroscope are considered, the relation to astrŏnomy of all we have studied in this chapter becomes apparent, and the fact is readily admitted that the spectroscope, with its close and efficient ally, the photographic plate, has given us what is termed our "new astronomy."

ASTRONOMICAL USES OF THE SPECTROSCOPE

Eighty years ago Auguste Comte said that "the chemical constitution and the physical

state of the heavenly bodies must forever remain unknown to us." But this *savant* did not reckon with the spectroscope, which became a factor in astronomical research in less than twenty years after his prediction. Through it, the composition and structure of sun and star have been disclosed. This instrument also tells us much about a star's motion—whether it is moving toward or from us, at what velocity, and whether it is revolving. It reveals, too, the chemical elements composing a star, whether it is solid or gaseous, and whether it has an atmosphere. About half of the known elements have been found to exist in the sun. Elements unknown upon the earth have been found in some of the heavenly bodies.

The workings of the spectroscope are easily understood. We have all noticed the increasing shrillness of the whistle of a locomotive as it nears us at great speed, and we have noticed that it grows lower in pitch as the train recedes from us. The violet end of the spectrum, with its short waves, corresponds to the high pitch. So if a star is coming toward us at a high velocity, the light waves will be shortened, and the dark lines of the

spectrum will be deflected toward the violet end. If it is receding, the waves will be lengthened, and thus the dark lines will be deflected toward the red end. If the lines oscillate, it will be known that the body is revolving.

The time of rotation of the sun and planets has also been determined by the spectroscope. It also makes the study of the chromosphere of the sun possible on any clear day. Without it, this scarlet envelope could be seen only at times of solar eclipse.

Light is "the astronomer's necessity"; but the foregoing observations show that without the spectroscope, it could not render the greatest service.

XIII

"THE WORLDS AND THE WORD"

ALL peoples, except those of the very lowest culture, are said to have some theory concerning the origin of the universe. Many of these theories are grotesque; and the best of them are altogether inadequate to explain the work of creation unless they are based upon the word of the eternal God, the Creator of the heavens and the earth. He says that the worlds were framed by His word: that He spoke, and they stood fast; that the creative work pertaining to our earth was accomplished in the brief period of six days; and that at the end of that time, it was perfect before God.

Some refuse to accept this God-given explanation, and propound theories of their own human reasoning. But they are compelled to assume the existence of matter, speculating only as to its later divisions and condensations into suns, planets, and satellites. They have found no way of creating the material, or "star dust," out of which the heavenly bodies are made.

Some ostensibly give Omnipotent Power the credit for the creation of the original matter; but the fact that such renounce the Lord's statement concerning the time and method employed in the creation of this world, destroys faith in the Word and eventually in its Author.

Why not take a perfect world from the hand of an all-wise Creator as quickly as a nebulous mass of matter endowed with gravitation and motion?

One of these man-proposed theories of the origin of our solar system, the nebular hypothesis, claimed wide attention during the last century. It was evolved chiefly from the speculations of an eminent Frenchman, Laplace. He was a brilliant man, being recognized as the greatest of French mathematicians; and so profound was his knowledge of celestial mechanics, that he is called "the Newton of France." He is charged, however, with one grave fault, which his contemporaries deplored,—that of using the theories, calculations, and discoveries of others as if they were his own, giving credit to himself only. Perhaps this is why he was so ready to rob the Creator of the worlds of His pre-

rogative; for Laplace fearlessly announced that he could construct the worlds without a god; he "had no need of the hypothesis of a god." Emboldened by these assumptions, later scientists essayed to fill the infinitudes of space with suns and systems of suns after the same plan; while others adapted the basic principle of the Laplacian theory to all created things.

The theory propounded by Laplace in 1796 presented at the beginning of the development of our solar system a ready-made sun with a nebulous or highly heated gaseous envelope filling all the limits of our system to Neptune. This nebulous mass, he concedes, had been endowed with a slow rotary movement. As it cooled, it contracted, and becoming smaller, increased in velocity; so that in time, the centrifugal force equaled gravity, and a ring of this gaseous matter separated, or flew off, from the sun. This ring continued to rotate, and finally broke; and some portion of it, presumably, being a little more dense than the rest, gathered the other parts about it, and developed into an independent body revolving around the parent nebula. This was the beginning of Neptune. In time,

this offspring threw off a ring, which became a satellite revolving about it. The original nebula, as it cooled, continued to throw off rings; and the planets formed from these rings, in turn threw off rings, which developed into satellites. An ingenious idea, but gravely false! Well might the Lord have said to the author of this speculation, "Where wast thou when I laid the foundations of the earth, since thou understandest so fully how I wrought the work?"

The interesting way in which Laplace first presented this novel theory to the world, brought to it immediate and favorable attention, though he is said to have offered it with diffidence, knowing that his speculations were unfortified by proofs.

The thinkers of his time, being captivated by his logic, acquiesced in the theory; and for more than a century, his self-created world theory dominated scientific thought. Through this source, it insidiously found its way into the world's literature and schools, until people generally, without sensing its real spirit of infidelity, accepted it.

As we have said before, the theory came to be applied in an adapted form to the origin

of all material things; even man, who was made in the image of God, being counted an accident, not a creation planned and executed by the Infinite Mind. Mr. Darwin sees him in the dim ages of the past, by some twist of fate, blindly forsaking his apish ancestry, and developing into the most intelligent creation.

Time is the test of all things; and under this test, many of man's most cherished, fine-spun theories and hypotheses have proved of little worth. The Laplacian theory is one of these. With new discoveries, and the exact observations that have come with increased astronomical facilities, the theory has received an adverse pronouncement from the *savants,* except in its basal idea, that of evolution.

Those who readily relinquish the Word of God, which has stood the test of the ages, for some man-made theory, need not wonder when they see the walls of their pet ideas crumbling. It is better to "hold fast that which is good;" better to "buy the truth, and sell it not," for truth is eternal. The most popular error in time will be supplanted by truth or by some new error.

Garrett P. Serviss, in "Curiosities of the Sky," says that "Laplace's hypothesis can

certainly find no standing ground either in the Orion nebula or in those of a spiral configuration. Some other hypothesis more consonant with the appearances must be found."

Professor Moulton, of Chicago University, says, "It is certain now that the ring hypothesis as to the origin of the planets can no longer be held as a possibility."

Professor Proctor, an astronomer of note, says, "There is no observable evidence in the heavens confirmatory of the nebular hypothesis."

Professor Harold Jacoby, of Columbia University, after stating several points where the Laplacian theory does not accord with fact, lays down this principle: "As a matter of logic, a correct theory must explain every observed fact within its range. A single contrary observation may destroy logically an entire theory, no matter how many observations seem to confirm it."

According to this reasoning, the Laplacian theory has heard its death knell; for many "contrary observations" have been made against it. Some of these to which astronomers direct attention follow:

The orbits of the remote planets are more nearly circular than those which are nearer the sun. The correct working of the theory would require the opposite condition.

The theory calls for concentric orbits of all the planets, no intersecting of one orbit by another. The orbits of hundreds of the minor planets so intersect and interweave that it is said that if they were made of wire, one could not be removed without taking all of them. Laplace did not reckon with these, for they were unknown in his day.

The theory demands that not only the planets, but all their satellites, shall revolve in the same direction. The two outer satellites of Jupiter, and also the outermost of Saturn, revolve in the opposite direction from what the theory demands. These, too, had not been discovered in Laplace's time.

The theory demands that no satellite shall revolve around its planet at a greater speed than the planet rotates. The inner moon of Mars refuses to heed this limitation, and bounds away at a speed three times what it should have, performing a revolution in eight hours, while Mars requires twenty-four hours

to make a rotation on its axis. The inner ring of Saturn also completes a revolution while the planet turns only half way over.

The thousands of nebulæ that have been studied do not accord with conditions demanded of nebulæ by the ring hypothesis.

Why continue to list discrepancies? The theory as a theory is dead. Present-day astronomers pronounce it so. Some have already essayed to build upon its remains another theory; but this is more fantastic and speculative than the Laplacian. Surely here is where the wisdom of man is foolishness with God.

Though the theory as a whole is found untenable, it has done its deadly work. From the evolution of worlds to the evolution of life was but a step. The evolution idea has fastened itself upon all creation. It permeates the world's thought and life. It has subtly undermined the faith of the people in God's Word, and therefore in God Himself. Surely the Saviour suggests this faithless condition when He asks, "Nevertheless when the Son of man cometh, shall He find faith on the earth?"

Sometime men will come to know that "the worlds and the Word speak but one language, teach but one set of truths."

The peerless orator, W. J. Bryan, is one among a few thinking men and women of this time who sense the insidious evil lurking in the theory of evolution. When men discard a part of the Bible for cold human speculations, they soon lose faith in the rest of the Word, and their religious foundation is removed. Without enlightened religious convictions, civilization dies. Sensing the imperative need of reform, Mr. Bryan is devoting his gifts to the work of reclaiming the people to the faith of their fathers by denouncing fearlessly the evolution idea, as applied to any phase of the original creative work. He appeals to all worshipers of a miracle-working God to help "bring the world back to a real belief in God and to the Bible as an authoritative guide." Surely we who have heard the call of Revelation 14, "Worship Him that made heaven, and earth, and the sea, and the fountains of waters," can answer this appeal whole-heartedly.

Every song is said to close "with the keynote with which it began, and the brief ca-

dence at the close hints the realms of sound through which it has tried its wings;" so this volume closes with the alpha keynote: "The heavens declare the glory of God; and the firmament showeth His handiwork. Day unto day uttereth speech, and night unto night showeth knowledge." Happy are they who find nightly pleasure in beholding and contemplating the heavenly vision as portrayed in the blue of the celestial sphere.